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FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS

by

THE USE OF COCHRANE METERS

HARRISON SAFETY BOILER WORKS
PHILADELPHIA, PENNA.

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TO PLACE IN BINDER CUT OFF ON DOTTED LINE AND PUNCH CIRCLES

FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS

By Measuring and Recording Boiler Feed, Condensate,
Blow-Off, Heating Returns, Cooling Water, Etc.

Through the Use of
Cochrane Metering Heaters
Cochrane Independent Meters
Cochrane Metering Hot Wells
Cochrane Precision Meters

"*Quantitative knowledge
is the key to efficiency*"

HARRISON SAFETY BOILER WORKS
Established 1863
17th STREET AND ALLEGHENY AVENUE
PHILADELPHIA, PA.

PUBLICATION No. 820 COPYRIGHT, 1917

COCHRANE METERING HEATERS

and the several combination forms of Cochrane Metering Heaters and Cochrane Independent Meters, including Metering Hot Wells and Meters used in connection with Closed and Open Heaters and Exhaust Steam Heating Systems, and the Cochrane Flow Recorder, are covered by numerous

UNITED STATES PATENTS

Issued, Granted and Pending

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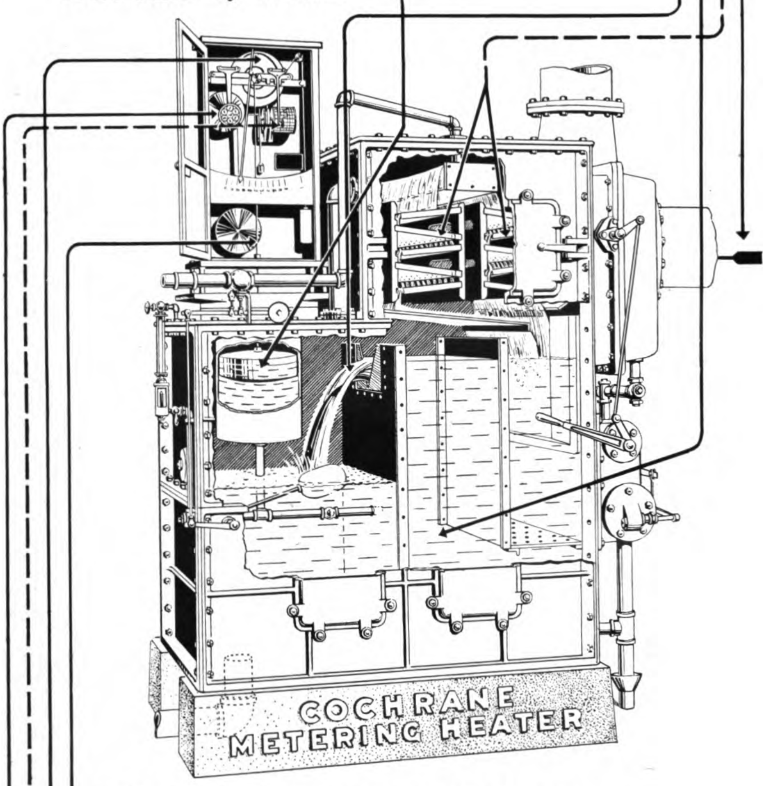
Pertinent Questions

How many pounds of water are your boilers evaporating per pound of coal?

Are they doing 6 or 7 pounds, or just a shade better than this, or are they up to the top notch, say 10 to 11 pounds of water evaporated per pound of combustible?

Unless you furnish your engineer with the means of knowing how much water the boilers are turning into steam, how can you expect him to improve the efficiency, and likewise the capacity, of your boilers?

1 **Steam purified of oil.**
2 **Water heated.**
3 Hot water delivered to still water chamber.
4 Water flows over weir.
5 Level of water in still water chamber ascertained by float.



6 Float stem actuates spiral cam.
7 Cam moves pen carriage equal distances for equal increments of flow.
8 Pen records on clock driven chart.
9 Integrator driven from clock actuated disk.

That's all there is to it.

THE COCHRANE METERING HEATER combines the functions of the celebrated Cochrane Heater (of which more than 10,000,000 horse power are in present successful and satisfactory service) with those of an accurate and reliable feed water meter.

The Heater Part

The exhaust steam by which the water is heated is first purified of oil by a Cochrane Oil Separator attached to and forming a part of the heater. The steam then flows in, around and between the trays, over which the cold water is being sprayed. This exhaust condensed in heating the water is conserved and utilized to form part of the boiler feed supply.

The heater also serves as a hot well or returns tank for the reception of condensate and trap discharges and as an automatic make-up water regulator to supplement such returns by the required amount of cold water.

The Meter Part

The combined water supplies, just before they pass from the heater to the boiler feed pumps, flow over a V-notch weir.

A powerful float, controlled by the head of water flowing over the weir, actuates a cam by which a pen carriage is moved equal distances for equal increments in the rate of flow.

The pen records the rate of flow at each instant upon a clock-driven chart. The area under the pen trace is proportional to the total amount of water passed. An automatic integrator gives immediate indication of totals.

Hundreds of Cochrane Metering Heaters are in successful operation, giving accurate and reliable measurements in the largest and best equipped plants of the United States.

KEEPING BOOKS WITH THE BOILER

The Cochrane Metering Heater Tells How Much You Are Getting For Your Money

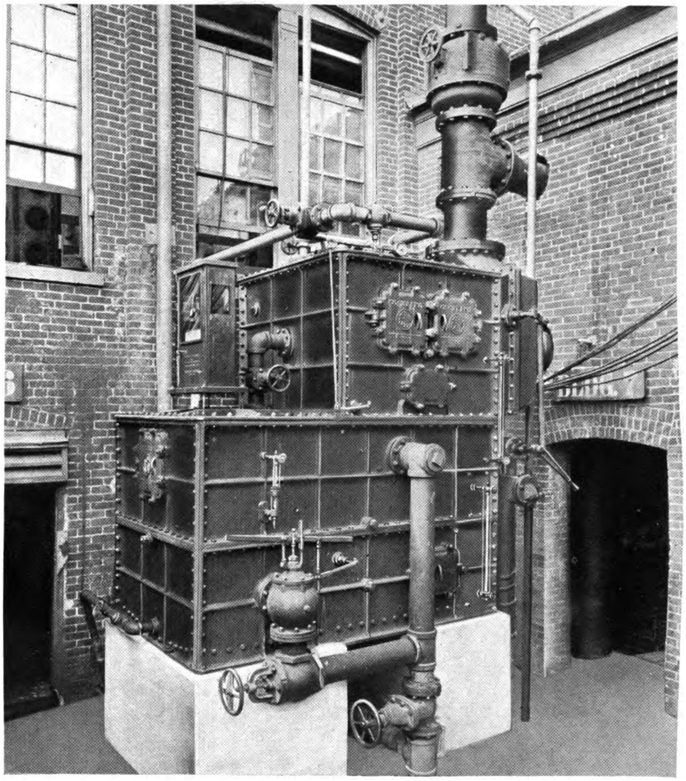
> **"For years we've been buying coal to boil water and now we want to know how much water we boil with the coal we buy."—*A Prominent Executive.***

The Cochrane Metering Heater initiates a new era in steam plant management. It puts emphasis upon a **high average** of performance, by indicating and recording the efficiency, hour by hour and day by day. A plant may be equipped with boilers of the best manufacture, with a chimney of sufficient capacity and height, with excellent fittings and specialties, and the coal may be the best grade obtainable, but who can tell whether the boiler performance is economical or wasteful? This is a matter concerning which knowledge is much better than guessing. Unless the engineer has at his command a means of ascertaining exactly how much water is evaporated per pound of coal, how can he be expected to concern himself with this question, which nevertheless means so much to you?

Without a record of the evaporation, who can tell whether you are getting all the steam that you should for the money expended for fuel? The fuel bill represents about 70 per cent. of the cost of power, but 10 to 40 per cent. of the fuel is ordinarily wasted.

Coal To begin with, how much of the fuel that you pay for is rock, ash and water? You should not take the coal company's word for this.

Is it the most economical fuel for your grates and boiler settings? Or would it pay to change the latter and burn a cheaper grade of fuel? The preventable loss from buying the wrong kind of fuel is frequently 10 to 15 per cent. and may run to 25 per cent. or more.



Cochrane Metering Heater installed in manufacturing plant

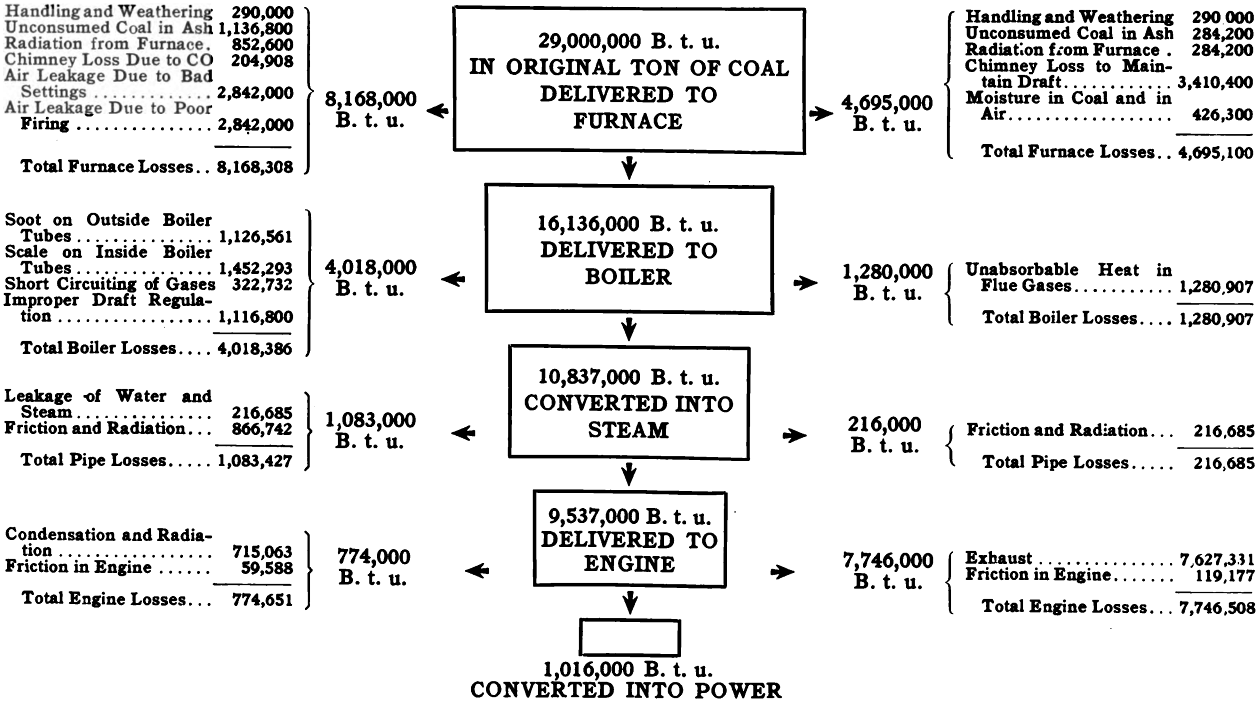
The Cochrane Metering Heater is the most practical form of coal calorimeter.

Grates How much fuel goes through the grates without being burned? Two to five per cent. may be lost in this way.

And how are you to know whether you are using too little or too much grate surface to carry your load with the draft and kind of coal used? Have you any way of finding out, as by measuring the evaporation per pound of fuel?

Firing Again, are the fires handled right? Do you know what thickness they should have for the draft used, or have you any means of keeping check on your fire-

Fuel and Heat Losses Between Mine and Crank-Shaft



PREVENTABLE LOSSES

Handling and Weathering	290,000	
Unconsumed Coal in Ash	1,136,800	
Radiation from Furnace	852,600	
Chimney Loss Due to CO	204,908	
Air Leakage Due to Bad Settings	2,842,000	
Air Leakage Due to Poor Firing	2,842,000	
Total Furnace Losses	8,168,308	8,168,000 B. t. u.
Soot on Outside Boiler Tubes	1,126,561	
Scale on Inside Boiler Tubes	1,452,293	
Short Circuiting of Gases	322,732	
Improper Draft Regulation	1,116,800	
Total Boiler Losses	4,018,386	4,018,000 B. t. u.
Leakage of Water and Steam	216,685	
Friction and Radiation	866,742	
Total Pipe Losses	1,083,427	1,083,000 B. t. u.
Condensation and Radiation	715,063	
Friction in Engine	59,588	
Total Engine Losses	774,651	774,000 B. t. u.

29,000,000 B. t. u.
IN ORIGINAL TON OF COAL
DELIVERED TO
FURNACE

16,136,000 B. t. u.
DELIVERED TO
BOILER

10,837,000 B. t. u.
CONVERTED INTO
STEAM

9,537,000 B. t. u.
DELIVERED TO
ENGINE

1,016,000 B. t. u.
CONVERTED INTO POWER

NON-PREVENTABLE LOSSES

	Handling and Weathering	290 000
	Unconsumed Coal in Ash	284,200
	Radiation from Furnace	284,200
	Chimney Loss to Maintain Draft	3,410,400
	Moisture in Coal and in Air	426,300
4,695,000 B. t. u.	Total Furnace Losses	4,695,100
	Unabsorbable Heat in Flue Gases	1,280,907
1,280,000 B. t. u.	Total Boiler Losses	1,280,907
	Friction and Radiation	216,685
216,000 B. t. u.	Total Pipe Losses	216,685
	Exhaust	7,627,331
	Friction in Engine	119,177
7,746,000 B. t. u.	Total Engine Losses	7,746,508

WHERE TO CUT POWER COSTS

JUST a little over half of the total heat losses in coal are preventable. Of these useless losses, this chart shows that the furnace wastes fifty-eight per cent., the boiler is responsible for twenty-eight per cent., the piping dissipates nearly eight per cent. and the engine is charged with five per cent. Bad boiler settings and poor firing are equally responsible for air leakage, which is the largest single cause of wasted coal. Are there not suggested in these figures points of worth-while attack?

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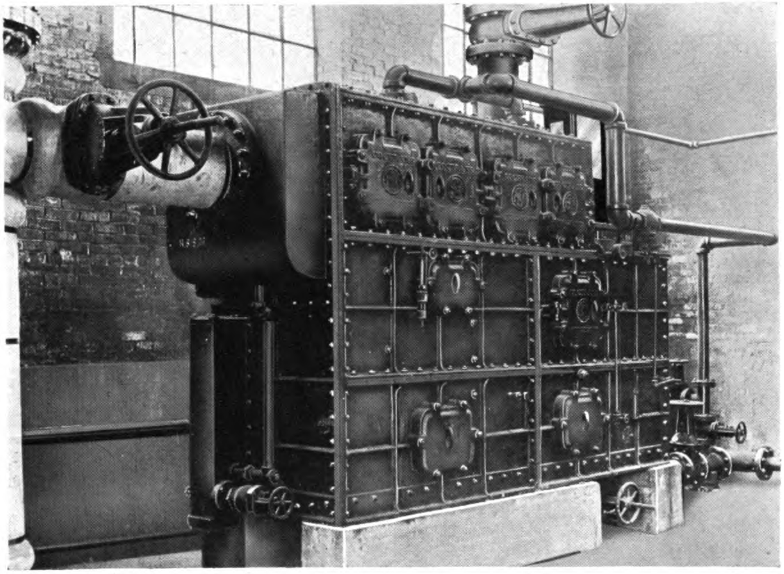
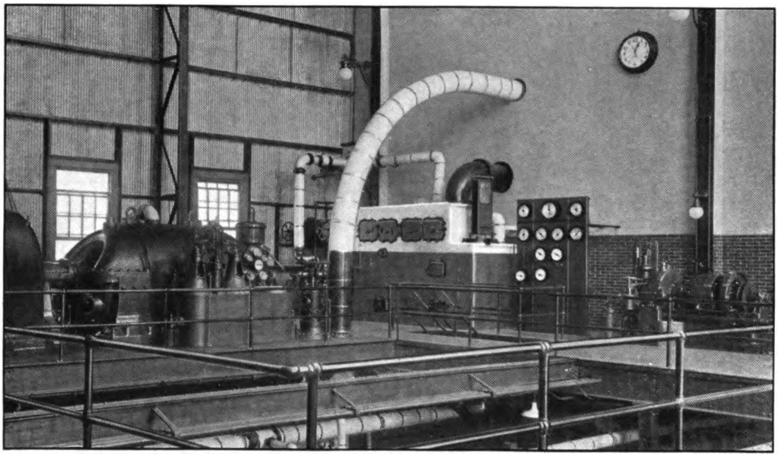


Cochrane Metering Heater in lumber plant

man, to know that he does not waste fuel by firing too much at once, by leaving thin spots and holes in the fire, or by too vigorous or improper use of the slice bar? The Cochrane Metering Heater, "The Cash Register of the Coal Pile," would watch this for you, and the saving in this item alone may amount to 10 per cent. or more.

Air Leaks What is the physical condition of your boiler settings? Another 10 per cent. of the value of the fuel may get away here, due to heating to chimney temperature and then passing to atmosphere millions of cubic feet of air which have entered through unsuspected leaks. If you have a Cochrane Meter to tell you that something is wrong, you will not rest until the leaks are stopped.

Draft That a chimney doesn't "draw" is not always the fault of the chimney, which may be correctly designed, both in size and height, for the amount of steam to be produced. If, however, the gases are greatly diluted with air, the draft pressure loss through fuel beds, boilers, breeching connection and chimney will be



Cochrane Metering Heater installed in central station

increased as the square of the volume; that is, a 50 per cent. excess of air will more than double the intensity of draft required. Furthermore, the lower temperature resulting from this excess air will reduce the intensity of the draft, which is due to the difference between the density of the gases inside the chimney and that of the air outside. That is, the use of the Cochrane Metering Heater in bringing up the boiler efficiency by pointing out losses due to excess air will, incidentally as it were, improve the performance of the chimney.

Gas Passages Defective baffling of the boilers, or slag, ashes and soot in the gas passages, may likewise interfere with evaporation to the extent of 4 or 5 per cent. A Cochrane Metering Heater will tell at once how much the evaporation has been increased by removal of soot or by fixing up the baffling.

Soot and Scale Scale on the inside and soot on the outside of the tubes are heat insulators, and frequently account for 5 per cent., and sometimes as much as 10 per cent. loss, not to mention tube renewals and other repair bills. Here, again, a Cochrane Meter will show how frequently it pays to blow the soot and to run the cleaner through the tubes, or will demonstrate the economy of installing a Sorge-Cochrane Hot Process Water Softener to keep scale-forming matter out of the boilers altogether.

Radiation Three per cent. of the heat probably escapes by radiation, much of it preventable. Try putting insulating covering on one of the boilers and see if it will not pay for the remainder. You can test this with the Cochrane Meter.

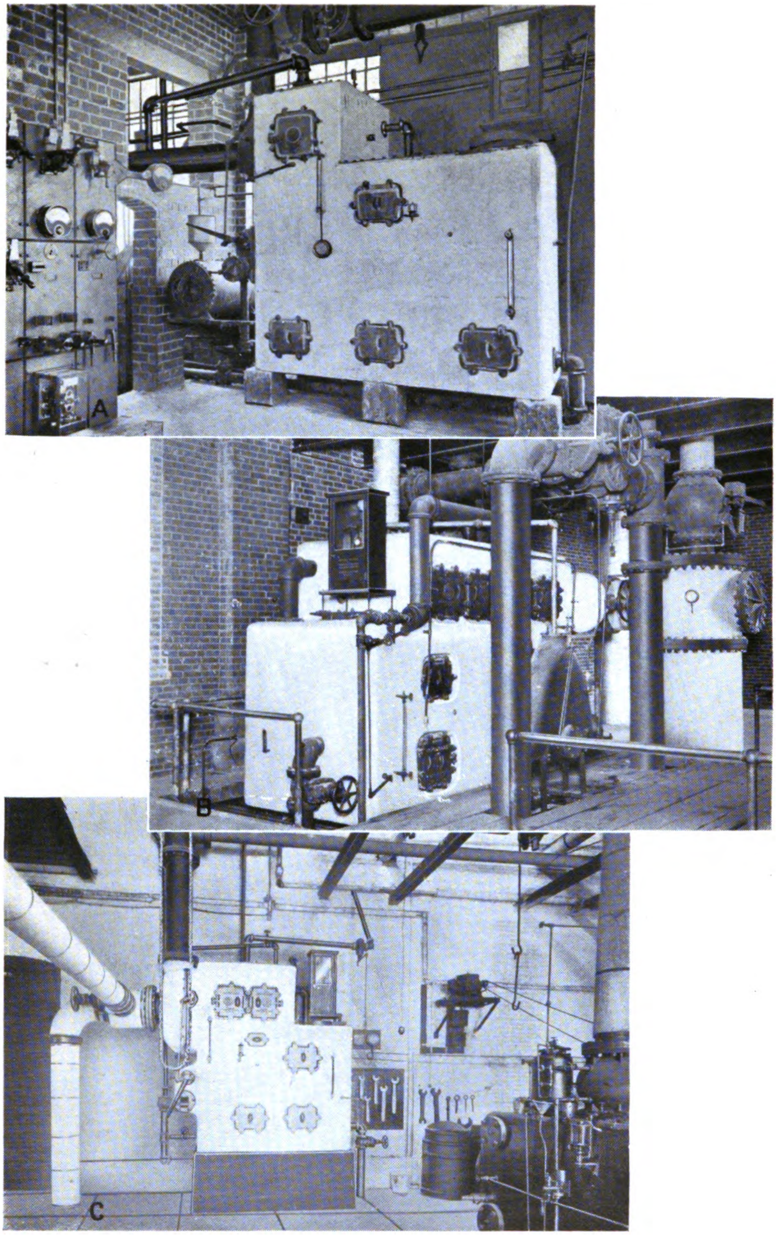
Where conditions appear to be unfavorable, due to variable load, poor coal, ignorant firemen, etc., our experience shows that the possibilities of saving are greater, and while all that can be expected of any plant is that it do its best, that best may be 10, 20 or 30 per cent. better than it is now doing.

The preventable losses above enumerated foot up to around 50 per cent., and it is no secret that many plants are running with a boiler efficiency below 60 per cent., and some even below 50 per cent., whereas they could, by proper methods, be operated between 75 and 80 per cent. At 50 per cent. efficiency a boiler requires just 50 per cent. more fuel to produce a given amount of steam than does a boiler at 75 per cent. efficiency. It has been said that "the average plant wastes just about a quarter of its fuel."

Hunt up your last year's coal bill, and see how 50 per cent., or even 25 per cent., of it would look added to your bank account.

NOTE—For the convenience of owners, managers and operators of steam boiler plants and others who are interested in securing and maintaining high economy, and who may wish to investigate further and apply the suggestions offered herein, we have made a comprehensive digest of current authoritative information, as given in Government reports, papers before engineering societies, etc., on the design, operation and management of steam boiler plants.

The collected data has been published in a volume entitled "Finding and Stopping Waste in Modern Boiler Rooms, Vol. II," and containing about 200 pages of closely printed text, tables and diagrams. It is of hand-book size, with flexible cloth binding, and sells for $1.00. Address Harrison Safety Boiler Works, 17th Street and Allegheny Avenue, Philadelphia, Penna.



Views of Cochrane Metering Heaters Installed

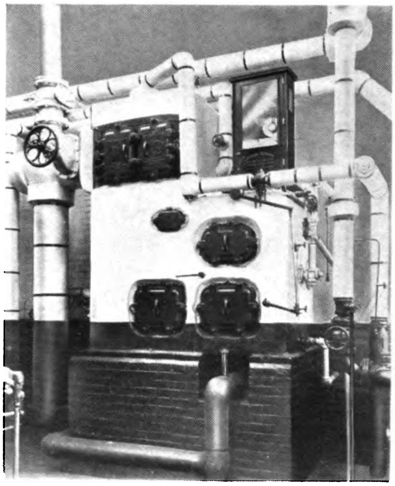
The Cochrane Metering Heater is a Profitable Investment

How much money is wasted through steam-plant inefficiency?

As an example, take a plant developing 1,000 boiler horse power 10 hours per day for 300 days per year. As a fair average, assume that this plant is using 4 pounds of coal per boiler horse power. This comes to 12,000,000 pounds per year, or 6,000 tons, which at the average price of $3 per ton has cost $18,000.

Now by checking up on the grade of the fuel, by seeing that none of it is lost through the grates, by teaching the firemen the proper methods of firing, by putting the boiler settings in good physical condition, by inspection and repair of baffling, by the removal of scale and soot from the tubes, by reducing radiation—by attending to some two or three, in some cases even one, of these items, the annual cost of fuel can be reduced astonishingly, certainly 10 per cent., which would amount to $1,800.

$1,800 would cover several times over the extra cost of a Cochrane Metering Heater. Even if the coal costs only $2 per ton the saving is $1,200, which again is greatly in excess of the extra investment. As has well been said, "What we need we pay for whether we buy it or not."



A Metering Heater Installation

Efficient Management in the Boiler Room

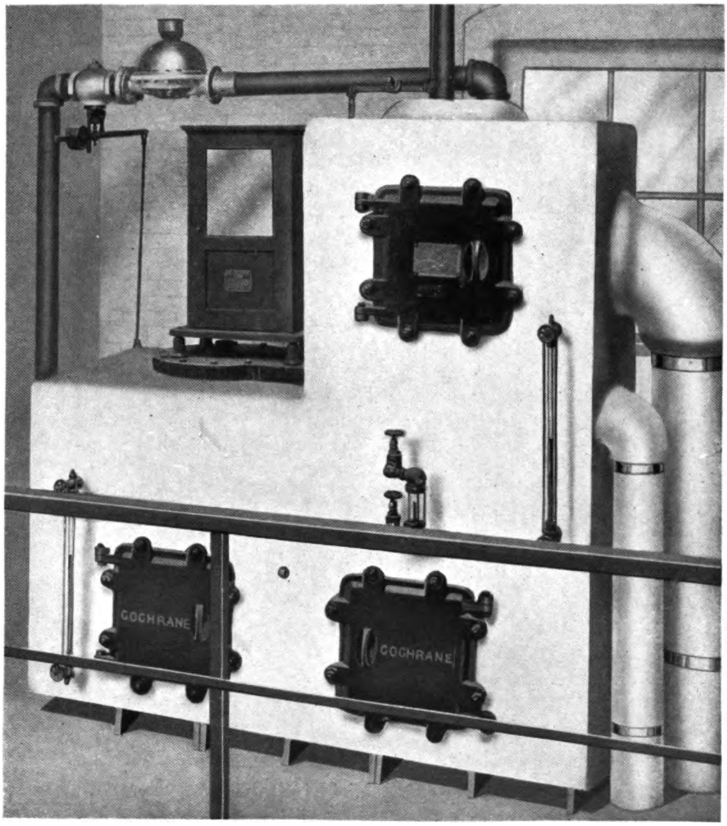
To secure better economy in the production and utilization of steam, knowledge of the efficiency of the plant and of whether or not that efficiency is bettered by each step taken for its improvement is required. As has repeatedly been pointed out by specialists in management, quantitative comparisons cannot be made without measuring devices. **Knowledge rests upon measurements.** When the savings from changes in apparatus or methods have been determined by means of measuring devices, it is then possible to decide whether it will pay to install such apparatus or to adopt such methods.

By having measurements and records, operations can be standardized, and individual rewards fixed for the maintenance of standards. As Mr. Harrington Emerson has said: "A standard is that which has been established by investigation or authority as reasonably attainable." Consciousness that his work is being scrutinized is a deterrent to slackness on the part of the workman, and reward for good results by increase in pay or promotion can be applied as a stimulus.

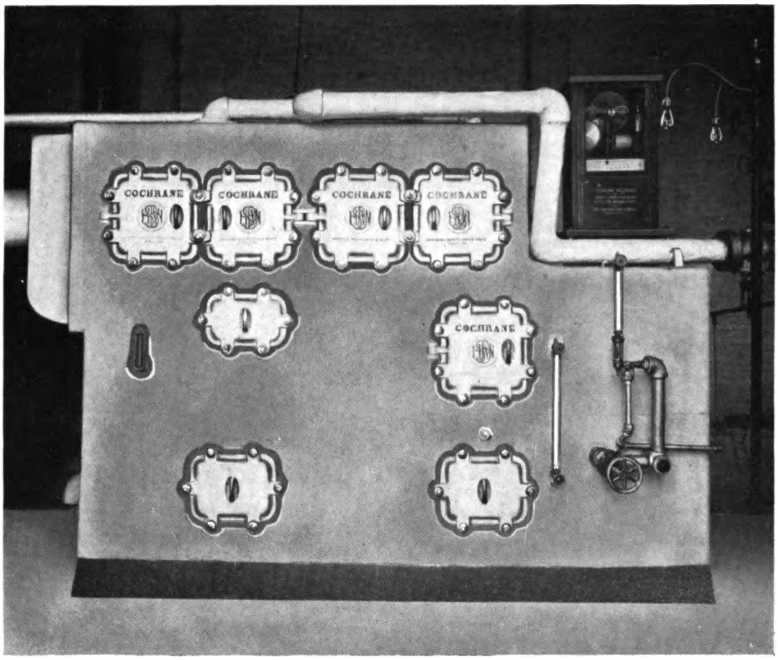
Any effective application of scientific methods of management to the steam plant, however, is dependent upon the provision of accurate means, such as the Cochrane Meter, for continously recording the water evaporated by the boilers. With a Cochrane Meter every day's run becomes an evaporation test. This is superior to the ordinary boiler test since it gives the over-all average rather than chance results.

The Cochrane Metering Heater does not make the fireman's work harder; it makes his work easier, because he has less coal to shovel. In a recent article, William Kent, the steam boiler expert and author of *Kent's Handbook,* says:

"The fireman in the ordinary factory boiler room is usually considered to be doing his full duty if he keeps up the required steam pressure, does not allow the water level ever to get either too high or too low, and keeps the boiler reasonably free from scale. **Having no means of metering the water or of weighing the hourly coal consumption, he knows nothing of the economy of the operation of the boiler and cannot be held responsible for it.** There is no one in the plant to instruct him how to do the firing so as to economize fuel, and lacking intelligent supervision he is apt to degenerate into a mere coal shoveler, and to do the shoveling in a manner which gives him the least trouble, that is, to fire large quantities of coal at a time, and have long rest periods between firings. The difference between a good fireman and a bad one is equal to the average fireman's wages. It would not be bad economy in many factories to raise the fireman's wages to the Ford standard of $5 per day if his efficiency could be brought up to that standard. **But it is not usually the fireman's fault that he is a bad fireman. It is the fault of the management in not providing any means by which his**



Cochrane Metering Heater for total feed water, together with disk meter for measuring cold make-up water



Cochrane Metering Heater installed in a flour mill

efficiency may be measured, or any instruction or apparatus by which his efficiency may be improved."

A good engineer takes pride in keeping his plant "up to scratch," and in showing high economy. He knows that the establishment and maintenance of a good record in the boiler room will inspire the men and may interest the management. He should be provided with the means that will enable him to do it, and means by which he can ascertain the effect of improved methods and keep a check on fire room results.

The engineer needs the Cochrane Metering Heater in order to get credit for his work. One man writes us, "The manager of this plant criticised the engineer for burning too much coal. It was his impression that he was operating 1,500 Boiler H. P., but after the Cochrane Meter was installed, he found that 2,000 to 2,200 H. P. were being developed. This fact helped to interest the engine and boiler-room force, who previously had looked upon the meter as a device to be used to criticise them, rather than to help them."

The Cochrane Metering Heater Shows What Load the Boilers Are Carrying

Most Economical Boiler Load

It is important to know how hard the boilers are being driven. There is a most economical load for any boiler, and in cutting in or laying off boilers, this should be considered.

It may, in some circumstances, be cheaper to keep all of the boilers on the load than to carry banked fires, but there is no way of telling except by measuring the evaporation at different loads.

What the Load Curve Shows

The distribution of the load throughout the day will often reveal significant facts. It may show how the times for various operations could be changed to advantage, or it may indicate that certain processes or machines are not started up promptly when the whistle blows, or are shut down before quitting time.

Control of Feed Pump

The meter will reveal irregularities in rate of feed that have a bad effect on the efficiency of feed water heaters and economizers, since when the feed pumps are idle or are running too slowly heat escapes unutilized, and when they are running too fast water is fed to the boilers cold. The meter will show up improper operation of boiler-feed regulators.

Boiler Capacity

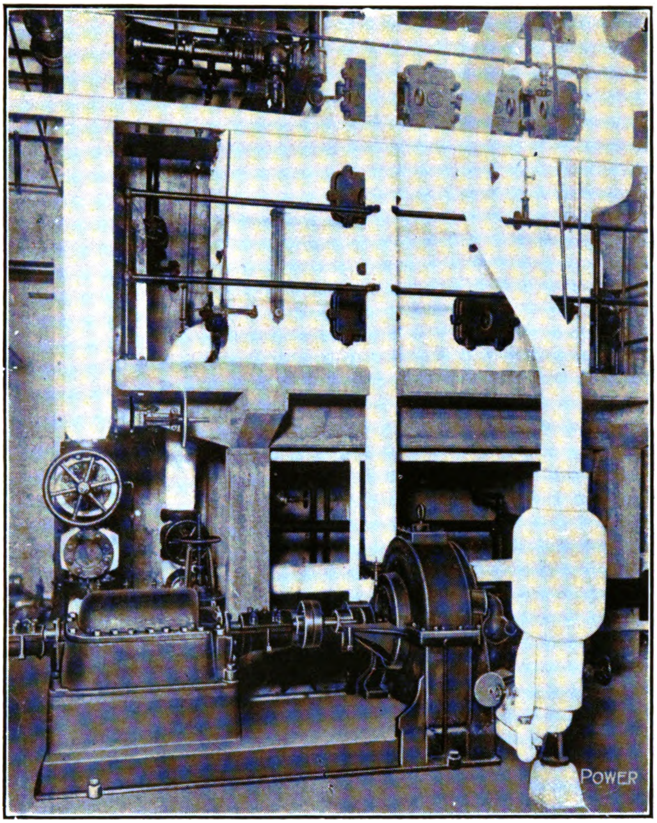
Before buying more boilers, investigate the capacity of your present boiler equipment. To illustrate, a certain concern was operating three boilers of a nominal rating of 300 horse power each, one of 200 horse power, and one of 60 horse power, and was planning the installation of a new boiler plant of three 500 horse power boilers. At a cost of about $750, a Cochrane Meter was installed to determine the exact load, before buying the extra boilers, and the meter showed that three 300 horse power boilers, instead of three 500 horse power boilers, would be sufficient. The saving of this 600 horse power of boiler capacity paid for the meter many times over.

Stoker Efficiency

As another instance, a large cement company bought a Cochrane Metering Heater, and immediately proceeded to check up the boiler performance and to study means of increasing the efficiency of the plant. Seven 300 horse power water tube boilers were then being operated. The inefficiency of the boilers was found to be due in part to unburned coal wasted by mechanical stokers and to excess of air entering the furnaces. Two of these stokers were replaced by stokers of another type and other changes were made, enabling the superintendent and engineers to report a wonderful saving. Only four boilers are now required, two of these being operated with the new stokers at approximately 200 per cent. overload, which, from the Cochrane Meter, they found to be the most efficient load. By these improvements, they have saved $30,000 in one year, and they are manufacturing cement with 4 pounds less coal to the barrel than before they installed the Cochrane Meter. Five men have been laid off from the boiler-room force.

Small Plants

The statement is sometimes made that a certain plant is too small to warrant the installation of a meter. This, however, is contradicted by experience in one of our own plants, where a meter was installed primarily for exhibition purposes. It was soon discovered that the evaporation was low and the causes were found in a large



Cochrane Metering Heater installed in a municipal plant

percentage of combustible in the ash, heavy infiltration of air through the setting, and a low draft resulting therefrom, which forced the fireman to carry too thin a fire. It was found possible, by improving the draft and changing the grates, to burn a cheaper grade of anthracite with less waste, also to lay off one boiler, thereby reducing losses from radiation and from banking fires. The result of these changes, and of stopping up air leaks, paid for the meter in six months.

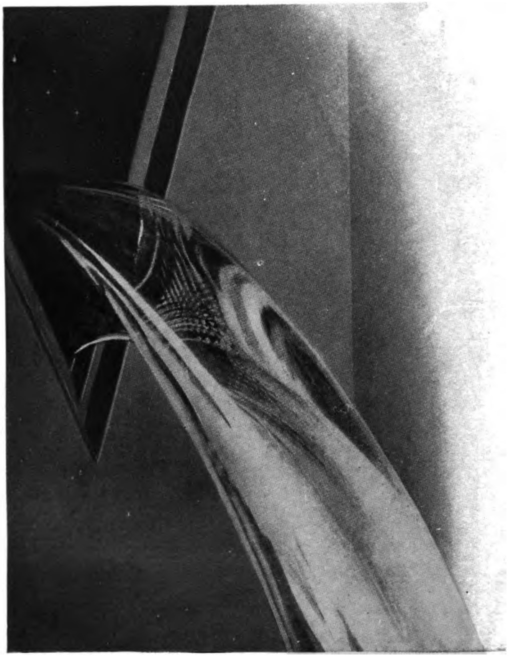
The Metering Heater Idea

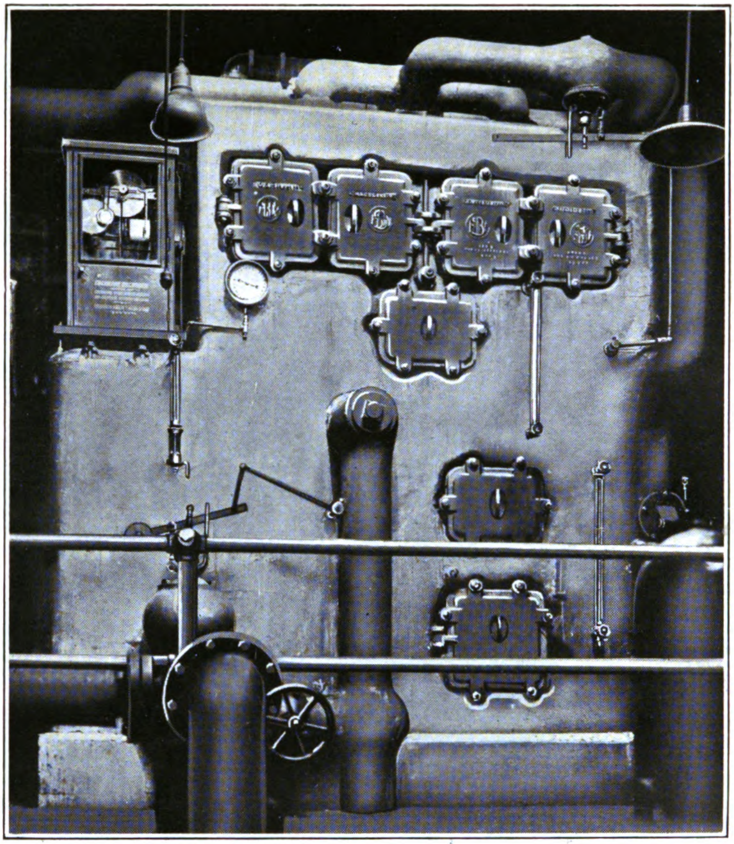
The necessity for some kind of meter for checking boiler evaporation was first impressed upon us some eight years ago. We saw that, while boiler efficiency could be improved 10 to 15 per cent. by feed water heaters, other possibilities in steam plant economy offered even greater rewards, but for their continuous attainment some means of detection and demonstration, that is, some means of continuous metering, were demanded. As this need was general, we set about finding the best way of meeting the requirements, taking up in turn each type of water measuring apparatus.

The siphoning volumetric type of meter, consisting of a chamber containing a siphon which discharges when the chamber is filled, was rejected because, among other things, of failure of the siphon with hot water. Tilting buckets were discarded for the same reason, also because of their liability to become filled with sludge and the fact that they give only a tally of total discharge, not a record of rate of flow, and because they require large tanks for storing the water before its delivery into the buckets and after its discharge. Considerable head is required between the source of supply and the boiler feed pump, and a large amount of heat is radiated from the storage tanks. Displacement meters had been in use for a long time, but had not proved reliable for metering hot water.

Flow meters of the Pitot tube type were discarded because they possess very little power for the operation of recording instruments and because the small orifices of the Pitot tube are liable to become stopped up by scale or sludge, while accurate indications depend upon calibration of the passage in which the tube is placed. Venturi tubes are designed to magnify the velocity head and thus provide power for the operation of the recorder, but for this very reason require high pressure, which prevents their being installed on the suction side of the pump. Both Pitot tubes and Venturi tubes are inaccurate at small flows, since, for example, at one-fourth flow the head available for the operation of the instrument is only one-sixteenth of the head available at full flow, and all movements of the recording and integrating mechanism between zero and one-quarter load must be performed by the power available from this one-sixteenth of the maximum head. The same applies to orifices. None of these flow meters can be easily inspected or cleaned and all are sensitive to the pulsations produced by reciprocating pumps.

Weirs have many advantages in the measurement of water. They are inexpensive. They are simple and accessible. They have been much investigated in many different forms. The ordinary rectangular weir is widely used in civil engineering practice, but unfortunately there is no one simple relation between the head and rate of flow, which is modified by end contraction effects. Several attempts have been made to construct weirs of special form, so that the relation between head and flow would be linear, or in simple proportion. This cannot be done, however, by mere mathematical analysis based upon simple laws connecting head and velocity; careful experimental calibration is required for each head and rate of flow for each size of weir and the straight line relation can be approximated only after endless cut and try work. Such weirs, because of surface tension and other causes, including geometrical relations, are inaccurate at


Appearance of the Flow through the V-Notch Weir



Cochrane Metering Heater installed in automobile plant

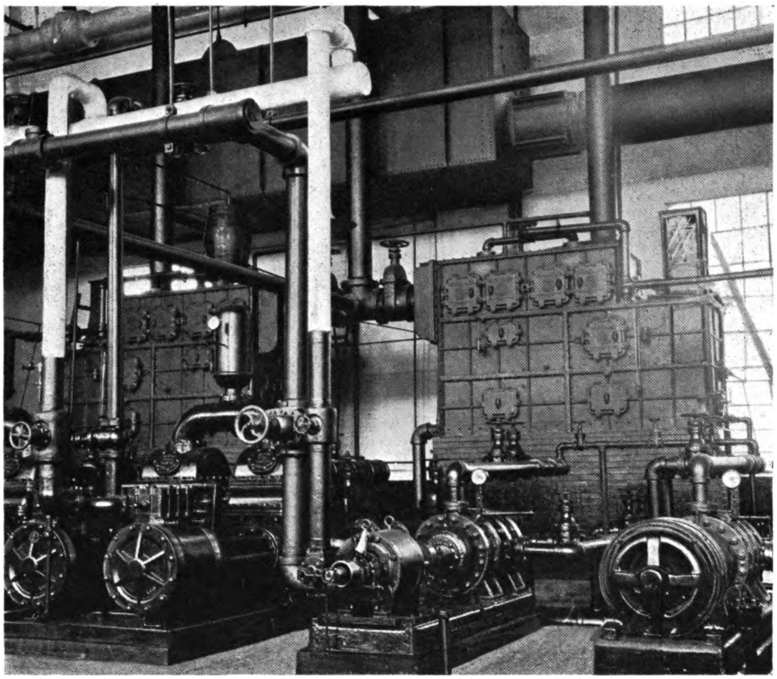
small rates of flow. In fact, the several serious disadvantages of the "flow-proportional-to-head" weirs much more than offset the slight simplification in the recording instrument which their use makes possible.

The consideration of weirs led us finally to the V-notch. The remarkable results obtained by Prof. James Thomson, brother of Lord Kelvin, with the V-notch form of weir in 1858 and 1863 were studied. He had shown that a simple formula could be used for V-notch weirs for a wide range of heads and rates of flow, and that the accuracy at small fractional flows was high, due to the rapid variation of head with change in flow at small rates. Subsequent work by Prof. James Barr, at Glasgow University, had also demonstrated that when installed under certain conditions, the rate of flow as calculated from the head observed would agree with the weight or volume actually discharged within one-third of one per cent. Extensive researches lately carried out in our meter laboratory have determined the relation between flow and head for *notches mounted in commercial meter chambers.*

Other advantages which make the V-notch peculiarly suitable for the purpose are its simple geometrical form, permitting it to be reproduced accurately and easily by machine shop methods, the ease with which it can be inspected or cleaned, the facility with which arrangements can be made for direct measurement of head so that the rate of flow can be ascertained independently of the indicating, recording or integrating instrument, and the fact that the storage capacity provided in the inflow and outflow chambers, that is, on the up-stream and down-stream sides of the weir, serves to absorb pulsations arising from the action of reciprocating pumps or other causes, thus enabling the meter to give an open chart which can be integrated, as distinguished from the badly confused charts often produced by other types of flow meters.

The V-notch weir requires an approach channel or still water chamber and, unless the water can flow away freely, an outflow or pump supply chamber, containing a float which controls a valve in the inlet connection to the meter. A meter comprising these parts can be set to receive water from hot well pumps or from an open heater and to deliver water to the boiler-feed pumps, and is herein referred to as an independent meter, since it is not combined with the feed-water heater. However, an independent meter receiving the discharge from an open heater requires extra space and head room, and introduces complexity in piping and control valves.

The use of an independent meter open to or vented to atmosphere is entirely inadmissible where back pressure is



Cochrane Metering Heaters installed in oil plant

carried in the heater and the water is heated to temperatures above 212 degrees F., since if water at temperatures above atmospheric boiling point is discharged into an open meter tank, part of it at once flashes into steam, with escape of vapor and loss of heat. Enclosing the meter tank is not a satisfactory solution of this difficulty, as will be shown:

Suppose the water in both heater and meter has been heated to 220 degrees F., and that the space above the water in both chambers has been filled with water vapor at that temperature and the corresponding back pressure of 2½ pounds per square inch. Then if the supply of steam to the heater is suddenly reduced, or the supply of water increased, the pressure of the water vapor in the heater may fall to atmospheric or even less, upon which the excess pressure in the meter will prevent the flow of water from the heater to the meter. In this way the boiler feed pumps may be entirely deprived of water. By the use of a manually operated valve, the excess pressure could be released from the meter, but the apparatus would not then be automatic and self-actuating, and, moreover, the adjustment would in all probability be neglected, so that, as a matter of fact, the relief valve would be left open at all times, converting the supposedly enclosed meter chamber into an open tank, so far as waste of vapor and loss of heat are concerned.

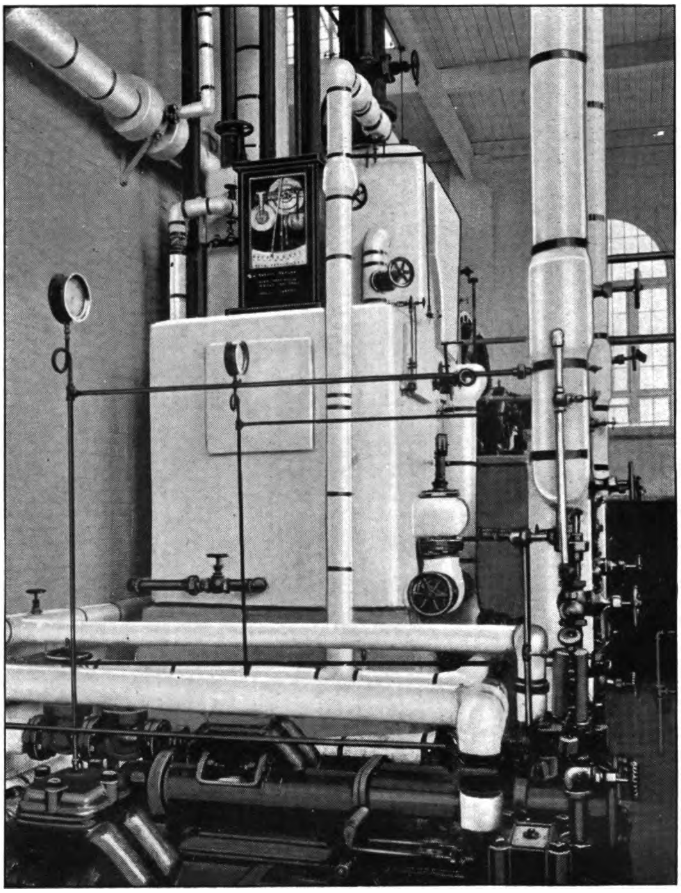
The best way of meeting all requirements was found in taking the Cochrane Heater, the most perfected form of feed water heater known, remarkable for its efficiency in heating water with exhaust steam without contamination by oil, and superimposing this heater above the weir chamber required by the V-notch. For reasons already explained, the notch chamber is placed in free communication with the steam space of the heater. A float is placed in the outflow chamber of the weir to control the admission of cold make-up water, thus rendering the apparatus complete, simple, self-contained and compact.

The Cochrane is the only original and true Metering Heater and is fully protected by patents.

Developing a Satisfactory Flow Recorder

Correctness of results presupposes precise knowledge of the properties of the weir or other measuring device used, but of equal importance is the flow recorder, which must translate the head upon the weir or orifice into a record of flow. This recorder must be both accurate and delicate in operation, and at the same time substantial in construction, and the manufacturing methods by which it is produced must insure absolute reproduction and duplication, so that when used in connection with weirs and weir chambers of which the properties are accurately known, it will give predetermined, dependable results.

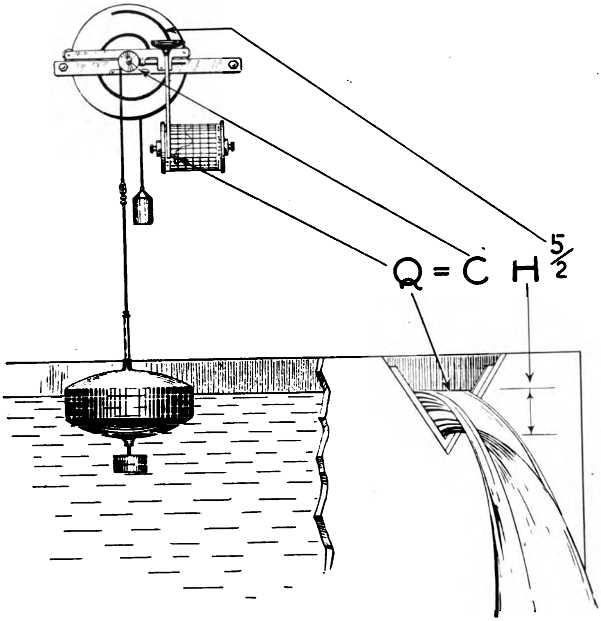
The recorder first tried by us required in its manufacture the use of as many different cams, some forty-two, as



Cochrane Metering Heater installed in silk mill

there were different angles and heights of notches in the system of meters; and these cams were all cut by hand. For these reasons accurate duplication methods of manufacture, involving the use of precise templates and other mechanical means of reproduction, were out of the question because of expense. In our new design, therefore, we provided for the use of a limited number of master cams, which could be duplicated with great exactness mechanically.

With the experience gained from the first one hundred recorders that we placed in operation, having learned their limitations and faults, we started out to design a more effi-

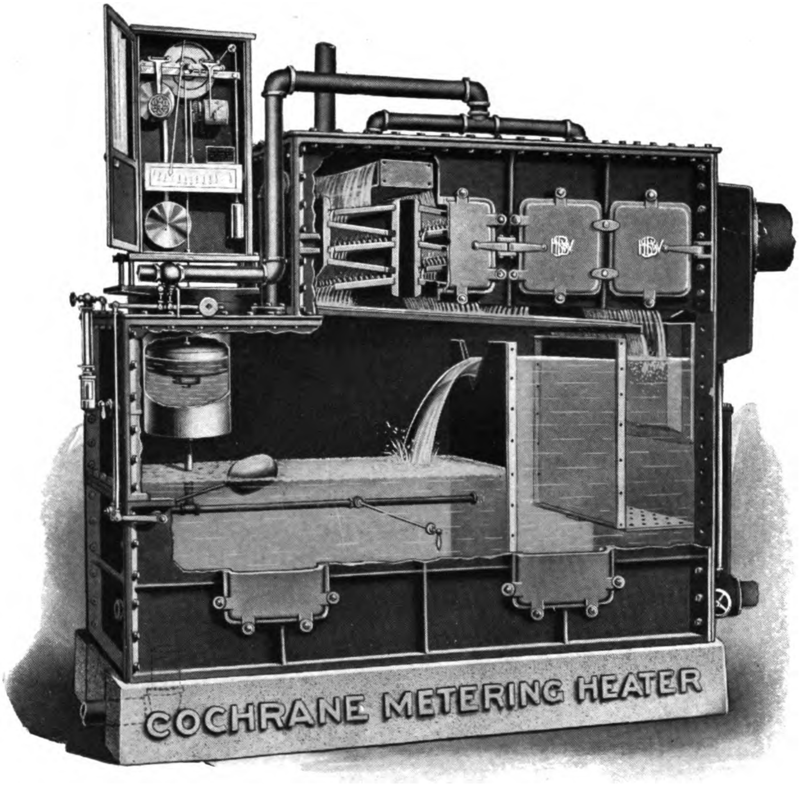


Correlation of float rise, cam rotation and pen displacement with the formula connecting rate of flow and head on the weir

cient recorder, one that would have less back lash and friction, and could more readily be adjusted by the user.

After building several different models, each representing an advance or improvement, we succeeded in producing a complete recorder which gives an accuracy in recording flow of water within one-third of 1 per cent., and when taking into account all variables, including 50 degrees F. variation in temperature of the water, has proved to be accurate within less than 1½ per cent. of actual weight. The Cochrane Recorder, together with our provisions for calibrating and testing, are described on pages 39 to 50 and 73.

Cochrane Meters have not only filled an existing need; they have also met practical requirements, as is shown by the fact that the capacity of those already sold exceeds 1,400,000 horse power. The Cochrane has been selected as the most suitable means available for measuring boiler feed and condensate by the engineers and officers of the most prominent concerns in the United States.



Design of the Cochrane Metering Heater

The heater part of the Cochrane Metering Heater is similar to a standard Cochrane Open Feed Water Heater. The boiler feed water, including condensed returns and make-up water, is heated, while falling over trays, by steam admitted through an oil separator attached to and forming a part of the heater. The heated water, including the steam which has been condensed in heating it, passes directly, or through a valve, to the still water chamber or approach channel to the weir.

The still water chamber is fitted with suitable baffles to break up local currents, in order that the water will rise without turbulence or commotion and flow to the weir smoothly. The weir plate is attached to a vertical cast iron baffle, reaching not quite to the top of the chamber.

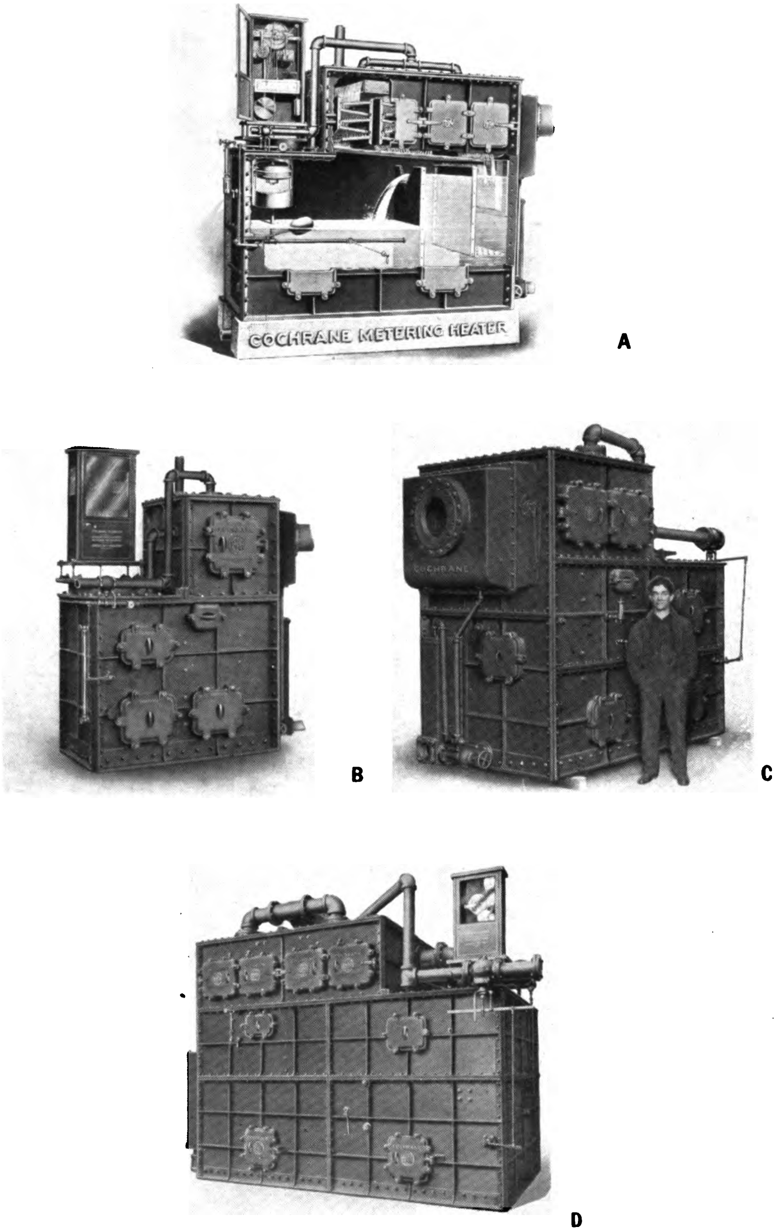
The discharge from the weir falls into the outflow chamber, which contains a float to control the cold water regulating valve for admitting make-up water. The regulating valve gear has been specially designed to utilize the entire stroke of the float, so that the total capacity of the outflow chamber is available for storing and restoring water. Irregularities in the rate at which water is taken by the pumps thus do not affect the inlet valve, and a reasonably uniform rate of flow over the notch is secured. The valve is of the balanced type, and very little work is thrown upon the float. The face and seat of the valve proper are protected from any cutting action of the water, thus preserving tightness.

The water is prevented from rising in the heater above a certain level by an overflow controlled by a trap, the latter receiving also the oily drips from the oil separator. On heaters intended for use in connection with engines exhausting freely to atmosphere, this trap is a simple water seal, while on those intended for back-pressure service a float trap is supplied, of the type successfully used in connection with Cochrane Heaters for over twenty years.

The steam space of the heater is in free communication with the steam space of the metering chambers, entirely obviating surges or pulsations due to varying supplies of steam or water. This is an exclusive feature controlled by our patents.

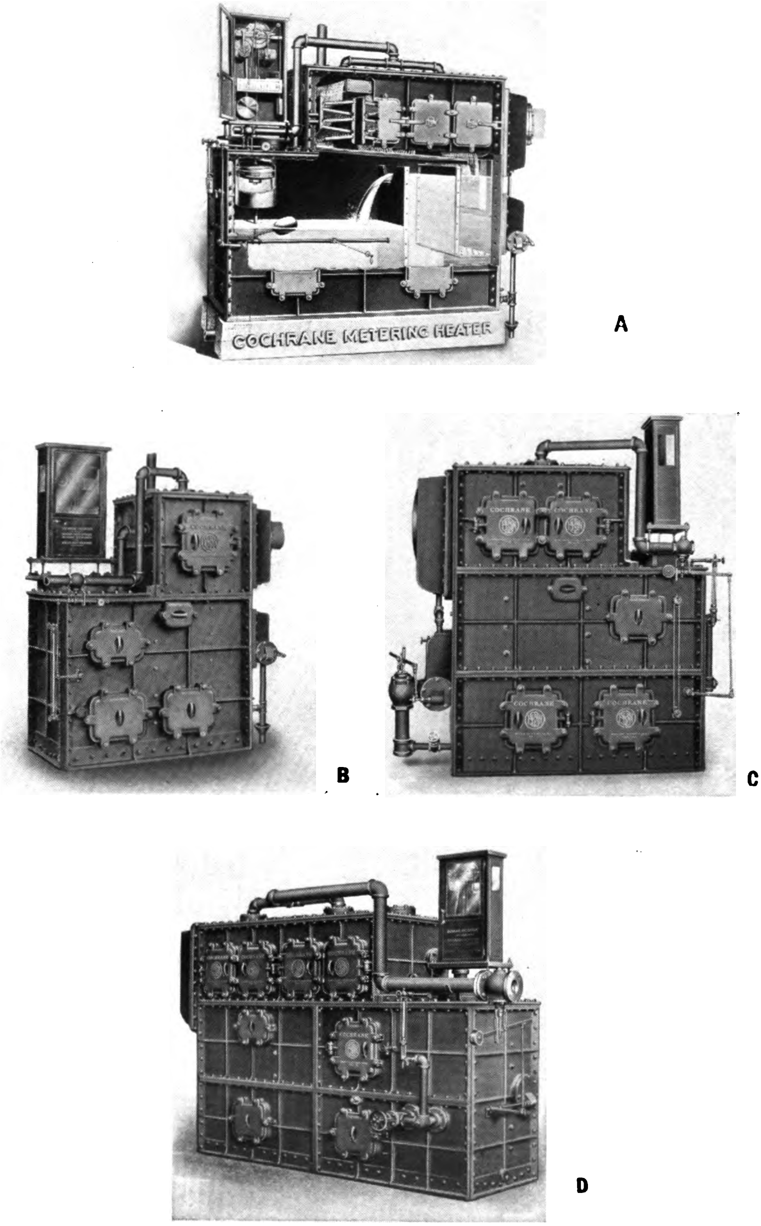
Where the Metering Heater is to be installed in connection with an exhaust steam heating or drying system, the oil separator is made of sufficient capacity to purify all the steam exhausted by the engine, including that which passes through a steam stack at the top of the separator to heating or drying coils or other apparatus. For greater convenience in cutting the heater out of communication with the exhaust steam piping, as when it is desired to inspect or clean the heater, valves are fitted which close off communica-

Metering Heaters



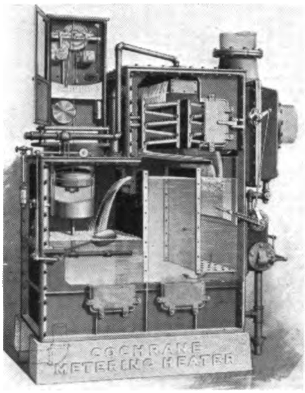
Cochrane Metering Heaters for use with engines exhausting freely to atmosphere
(24,000 Series)

Heaters and Receivers



Cochrane Metering Heaters and Receivers for use under back pressure
(25,000 Series)

Steam-Stack and Cut-out Valve Metering Heaters



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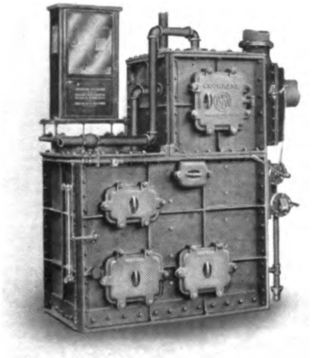

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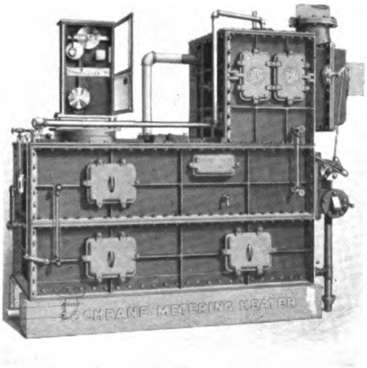


C

Cochrane Metering Steam-Stack and Cut-out Valve Heaters and Receivers with extra large oil separators for purifying surplus exhaust steam
(27,000 Series)

tion between the separator and the heater and between the heater overflow and the trap, both valves being controlled by a single handle, so that mistakes or oversights in manipulation are impossible.

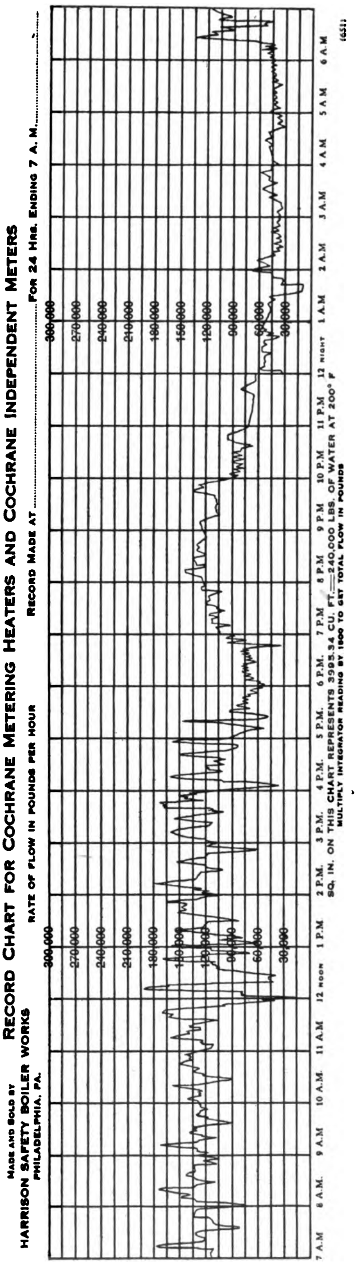
This arrangement, known as the **Cochrane Steam-Stack and Cut-Out Valve Heater and Receiver,** saves from $50 to $500 on the cost of equipment, as compared with an independent separator in a by-pass around a heater of ordinary construction, at the same time being more simple, occupying less space and being absolutely fool proof. The oil separator attached to and forming a part of every Cochrane Heater or Metering Heater is of a type of which over twenty thousand manufactured by us are in everyday use, protecting over 16,000,000 horse power of boilers from oil.

Where Cochrane Metering Heaters are installed in connection with exhaust steam heating or drying systems, the condensate or returns may come back at times in excess of the amount temporarily needed by the boiler feed pump, in which case provision can be made to store this excess of water

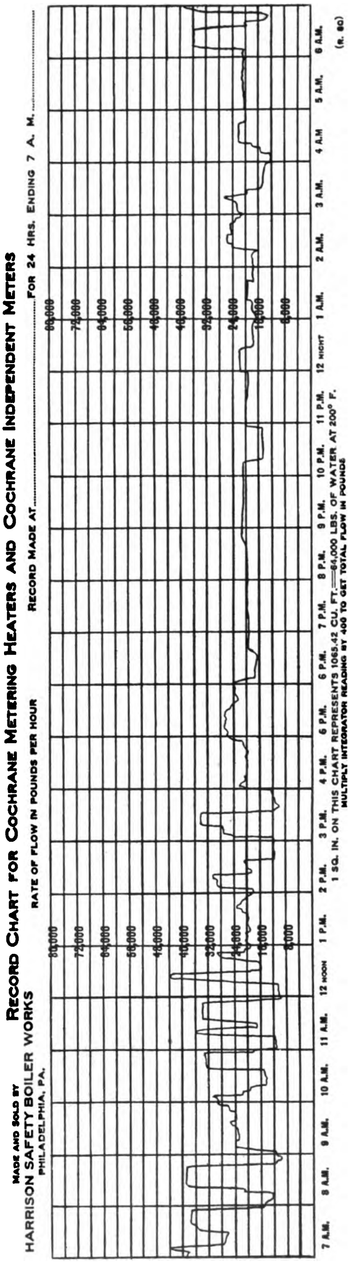
(1) externally to the metering heater, or
(2) in the heater itself, or
(3) the surplus can be by-passed to waste, or
(4) two or more of these methods can be combined.

The heater can be arranged to reserve the whole heating capacity of the trays for the cold make-up water, and the outflow chamber can be increased to give any desired storage capacity, which has the further benefit of smoothing out fluctuations in rate of flow due to the intermittent action of reciprocating boiler feed pumps.

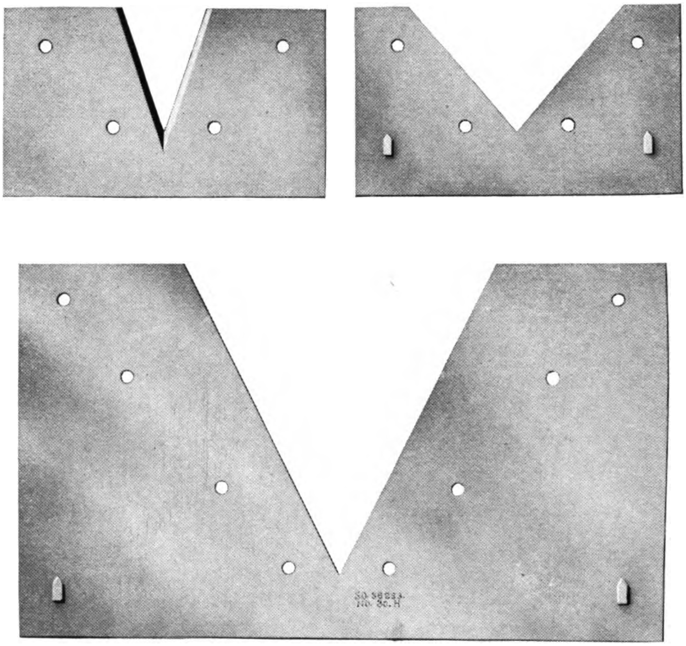
The materials employed in Cochrane Metering Heaters are selected for their durability. The shells and trays are made of cast iron plates, and the shell is heavily ribbed. Some makers of heaters use iron or steel plate for the shells and trays, but steel plate soon rusts out. The air and carbon dioxide gas driven out of solution when water is heated to



Cochrane Meter Chart from Central Station, showing variations in load



Cochrane Meter Chart from State Institution



Cochrane V-Notch Plates of various capacities, showing zero pointers, which are protected during shipment by lugs attached to them. The lugs are used for supporting the spirit level for rough leveling, and then removed

210 degrees F. in an open steam bath are especially active in attacking wrought iron or steel.

The Cochrane Weir or V-Notch Plate, shown above, is formed of two pieces of metal plate machined to the correct angle, chamfer and thickness of edge, and then accurately joined together while held in a suitable jig, and later tested by means of a limit gage, insuring absolute accuracy of angle. This method is greatly superior to scribing the angle upon a plate, cutting out with a hack saw and finishing with a file.

Soldered to the up-stream face of the notch plate are two zero pointers, so placed that their tips just touch the surface of the water when the latter stands at the geometrical zero level or apex of the notch. These pointers establish a reference plane for installing and aligning the entire apparatus, determining not only the zero level, but also showing whether or not the center line of the notch is vertical. As the notch plate is not subject to wear and is easily accessible for cleaning and inspection, known conditions of flow can thus be insured.

An auxiliary adjustable zero pointer is placed in a special gage glass attached to the weir chamber and is brought into agreement with the zero pointers on the notch after installation and while the weir chamber is still open and is filled with cold water. This auxiliary zero pointer subsequently serves as a means of adjusting the recorder to zero when the heater is in operation and filled with hot water and steam, suitable valves being provided by which the level of the water upon which the float rests can be drawn down to zero. **The ability to adjust the recorder while all parts of the meter are at working temperature is essential,** since the submergence of the recorder float, the length of the float stem, the position of the notch, etc., are all affected by the temperature. The relation of the several parts is shown in the illustration on page 49.

Accuracy in a V-notch meter is based upon a precise knowledge of the discharge at different heads of the notch as installed in the meter chamber actually used. This discharge is influenced by the arrangement and dimensions of the still water or approach channel, and as the manufacture of commercial meters involves a great number of combinations of meter chambers of different dimensions with notches of different angles and heights, the Harrison Safety Boiler Works has conducted a large number of individual tests in order to insure the accuracy of the Cochrane Meters.

In order to carry out precision tests expeditiously and inexpensively, a special **Meter Testing Plant,** shown opposite, was designed. In this laboratory, the flow of water can be measured with an error less than one-third of 1 per cent., which has made it possible to investigate the effects of varying the form of the notch, the effects of temperature upon rate of

Cochrane Meter Testing Plant

flow, the effects of variation of angle and alignment of notch, the effects of enlarging or contracting the approach channel to the weir, the effects of high water in the outflow chamber, etc. Many sources of small and unsuspected errors have been discovered, and much time and labor have been expended in perfecting refinements for their elimination. A detailed description of this plant is given in Cochrane Engineering Leaflet No. 18, which will be supplied upon request.

The Cochrane Recorder

The Cochrane Recorder is shown on page 41. A float resting upon water level with the water flowing over the weir actuates, by means of a cable and drum, a spiral cam so proportioned as to move a pen carriage equal distances for equal increments in the rate of flow, the shape of the cam corresponding to the law of flow of a given weir in combination with a given weir chamber, as actually observed in the testing laboratory. In this way the correct relation between float movement and pen movement is obtained.

In order that a high degree of precision may be realized in actual operation, it is necessary that back lash and friction be eliminated so far as possible. If there is back lash, the float may move a certain distance without a corresponding movement of the pen, while if there is friction the level of the water may change considerably before the float and pen will move.

In the Cochrane Recorder, back lash between the float and the cam has been eliminated by the use of a **cable and drum drive,** that is, a cable attached to the upper extremity of the float stem is wound about a drum rigidly fastened to the cam. Back lash between the cam groove and follower has been reduced to a minimum by machining the groove to uniform width and by using a follower pin only a trifle smaller in diameter, as required to avoid binding.

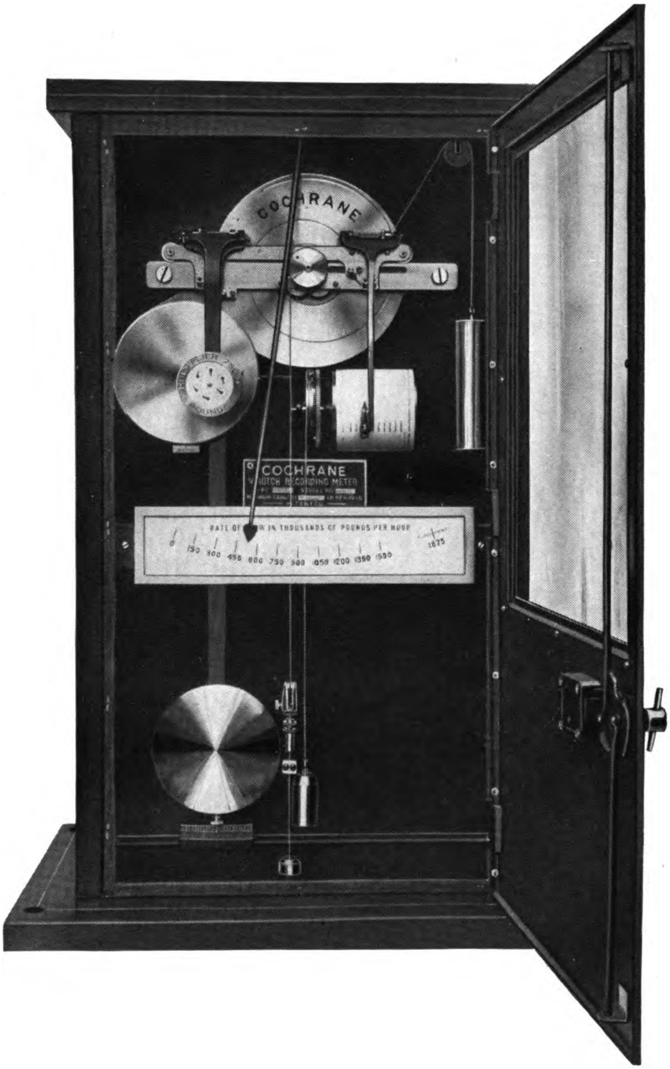
Friction has been eliminated by using a **float stem** which passes through a **self-aligning packing gland** of the multiple labyrinth type at the point where the stem emerges from the meter chamber.

The small, flexible **metal cable** is attached to the end of the float stem by a **micrometer screw,** providing delicate adjustment, and winds without friction upon a **cylindrical drum,** which with the cam is mounted upon a spindle resting in **anti-friction bearings.**

The cam slot is machined with the utmost precision by means of a master cam. The master cam is mounted close up to the blank in cutting, which is not feasible with cams cut upon cylindrical or other curved surfaces. Micrometer tests upon Cochrane spiral cams show an average deviation from absolute accuracy of only .002 inch.

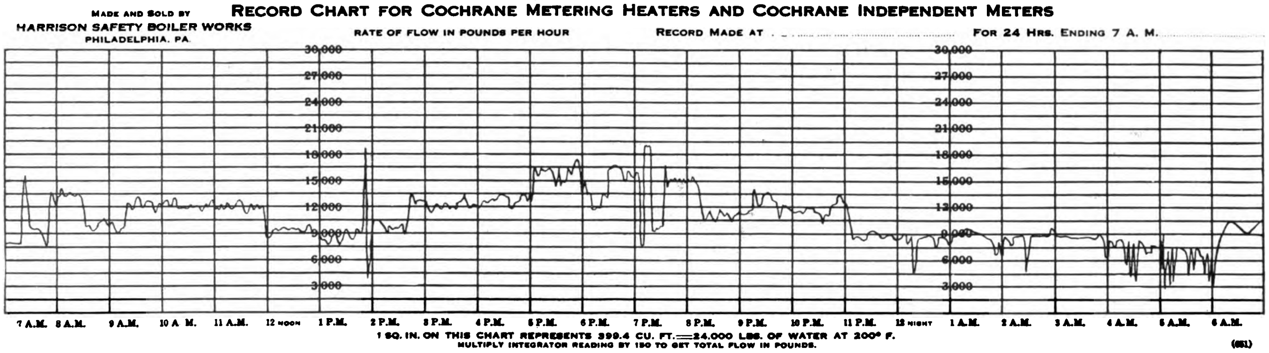
The spiral slot forming the cam is so proportioned as to give the total pen travel in two and one-half revolutions of the disk. The cam begins near the center of the cam for zero flow and proceeds toward the periphery for larger flows. Inasmuch as the rate of flow increases more rapidly than the rate of rise of the float, the radial movement of the pen follower is greater per inch rise of float as the maximum flow is approached. If the cam were cut upon a cylindrical surface revolving uniformly with the float rise, this would result in a steeper cam as the maximum flow is approached. With the spiral cam, however, the more rapid motion of the cam follower occurs upon the part of the cam farthest from the center of the disk, and therefore the steepness of the cam slot is ameliorated, thereby diminishing the friction and tendency to binding or self-locking.

The effect of a given amount of friction upon the accuracy of the pen movement depends also upon the power of the **float;** that is, the larger the cross section of the float at the water line the greater the force that it will exert for a given

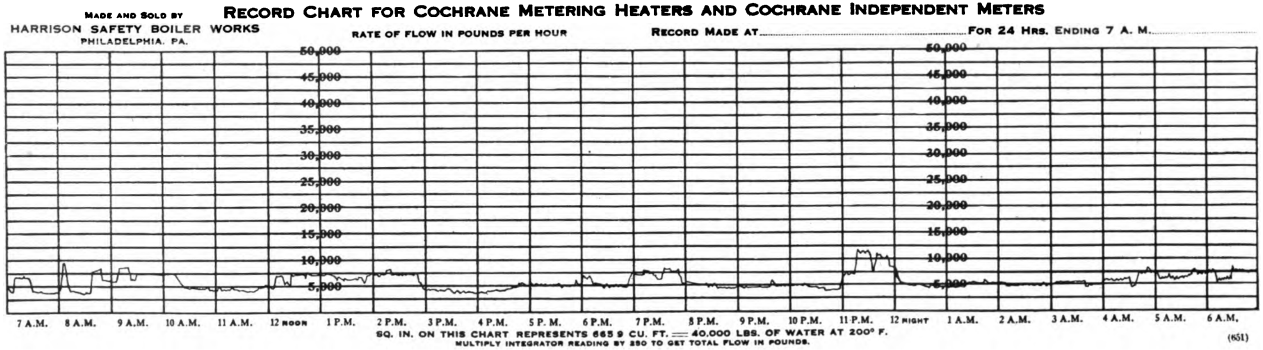


Cochrane Master Clock Recorder with door open, showing rugged simplicity and ready accessibility of weight-driven pendulum-escapement clock, which moves chart record and integrator disk in absolute synchronism. Note dust-proof door lining and triple clamp, which assures protection of instrument **against** dust and moisture.

Cochrane Meters



Cochrane Meter Chart from Mun'cipal Plant



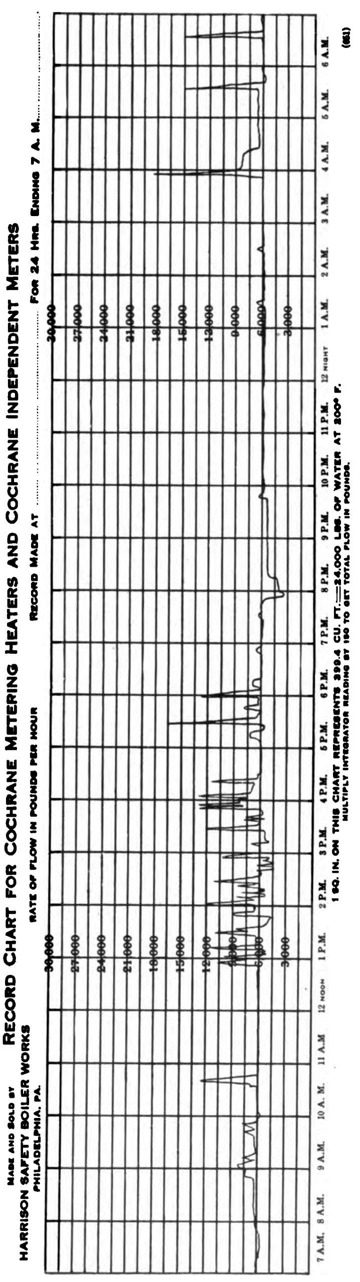
Cochrane Meter Chart from Office Building displacement of water level with respect to the float. The Cochrane Recorder is provided with a float 14 inches in diameter, properly ballasted so that it will hold the stem perfectly upright without other support or guidance. A variation of only .008 inch in the height of the water in the float chamber causes a visible movement of the recording pen. The float is placed either in the still water chamber or enclosed in a special galvanized chamber communicating with the still water chamber below the level of the apex of the notch. It is made from heavy, seamless, drawn copper.

The cam follower is attached to a carriage rolling upon horizontal ways. The follower cannot accidentally be moved to a wrong position on the cam, that is, cannot "jump the track."

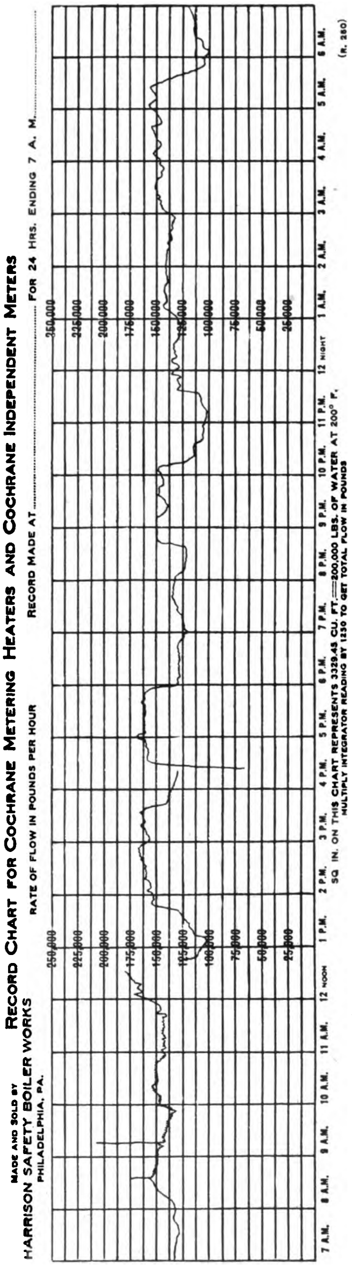
The pen holder is pivoted upon the carriage in such a manner that it is held by gravity against the paper chart carried on a clock-driven drum, and the entire pen and holder can be lifted off the carriage for filling or cleaning without loosening screws or other connections. A milled screw provides for adjustment to zero. The **pen** is of the siphon feed type.

The **chart drum** is of such diameter that the chart is exactly 12 inches long, and the direction of rotation of the drum causes the pen to progress from left to right on the chart, the ordinary direction of reading or writing.

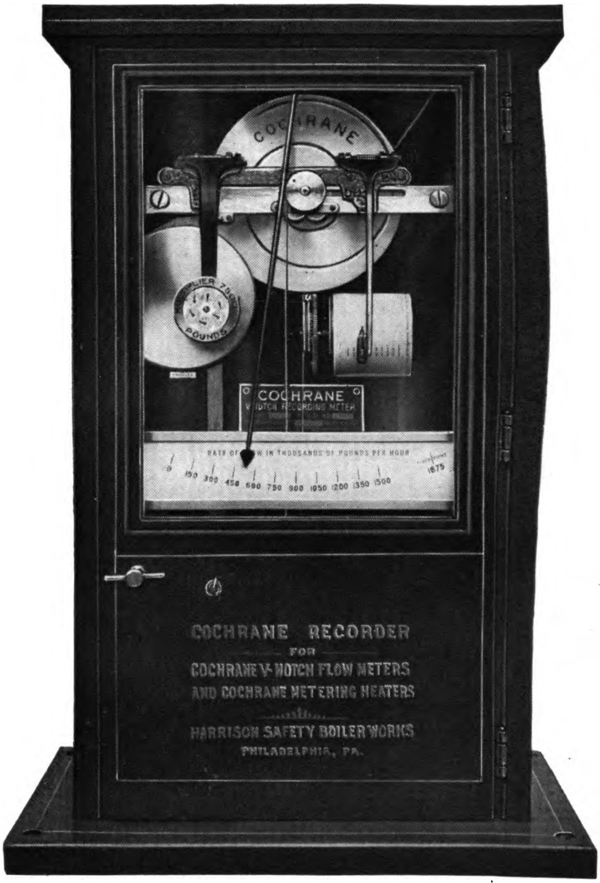
Also suspended from the pen carriage is an **integrator,** consisting of a counting train driven by a small, light roller disk held by spring pressure against a large aluminum disk driven by the clock at the rate of four revolutions per hour. The counting train roller stands at the center of the aluminum disk when the rate of flow is zero, and as it is moved away from the center equal distances for equal increments in rate of flow, the speed of the counting train is at all times directly proportional to the flow, hence the total movement of the counting train from one reading to another is directly proportional to the total flow during the corresponding interval.



Cochrane Meter Chart from Educational Institution



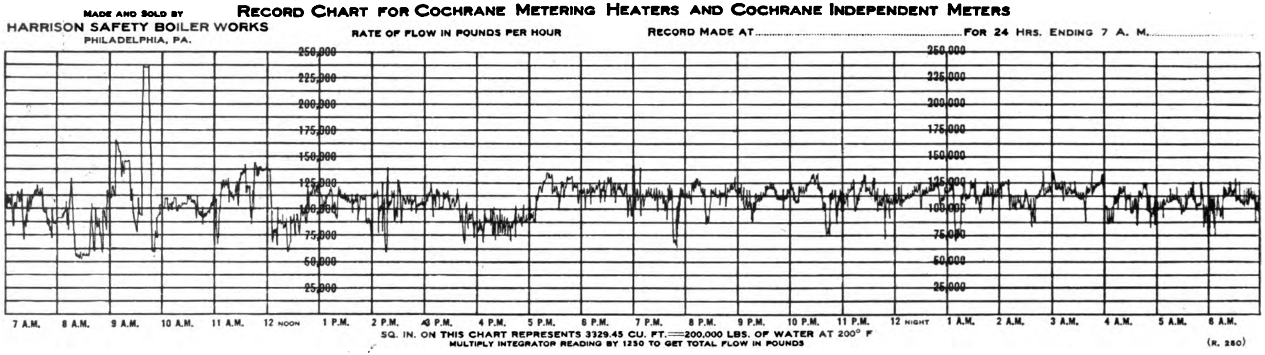
Cochrane Meter Chart from Steel Plant



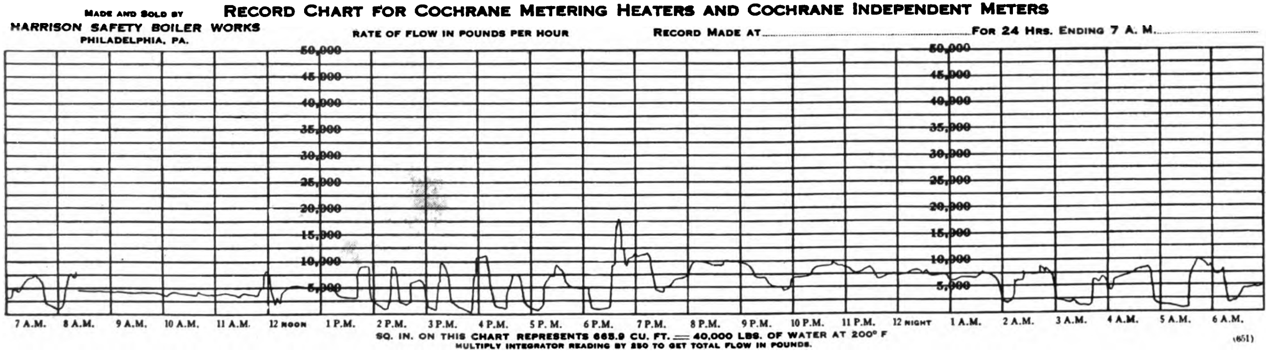
Cochrane Master Clock Recorder as it appears in service with door closed

Note how the **Visible Pointer** shows the load being carried at the moment. This reading can be compared with the pen record on the chart. The total flow for any given **interval** can be obtained by subtracting successive integrator readings.

Where it is desired to read the rate of flow readily from a distance, a large **visible pointer** traversing a scale occupying the whole width of the window in the door can be furnished.



Cochrane Meter Chart from Munition Plant



Cochrane Meter Chart rom Bakery

Single Clock Drive

A single clock is used for driving both the chart drum and the integrator disk, instead of the two independent clocks used heretofore on instruments of this character. Where two movements are used, they must be regulated independently and at the best can be synchronized only imperfectly.

Our new clock has been specially designed for the work, with a minimum of parts and wearing surfaces. It is weight-driven, the cable being wound about a drum which carries the chart drum. The pull of the cable is supported by substantial bearings upon either side of the drum, and the motion is conveyed to the first shaft of the clock by a flexible coupling, so that none of the cable pull is carried to the clock bearings proper. Inasmuch as the chart drum makes one revolution in twenty-four hours, this is the speed of rotation of the cable drum, which is of such diameter that the clock weight will fall a little less than half the height of the casing in that time.

Removal of the chart drum exposes a winding handle, the idea being that the operator, when changing records, will rewind the clock for a day's run, thus making it a regular routine that will become habitual, obviating the tendency to forget which is encountered with longer periods. However, the space for the movement of the weight permits the clock to run for two days, as over Sunday, without rewinding. The weight used is of large size, and as its entire energy is expended in two days instead of eight days, it will be seen that **the clock movement is of exceptional power.**

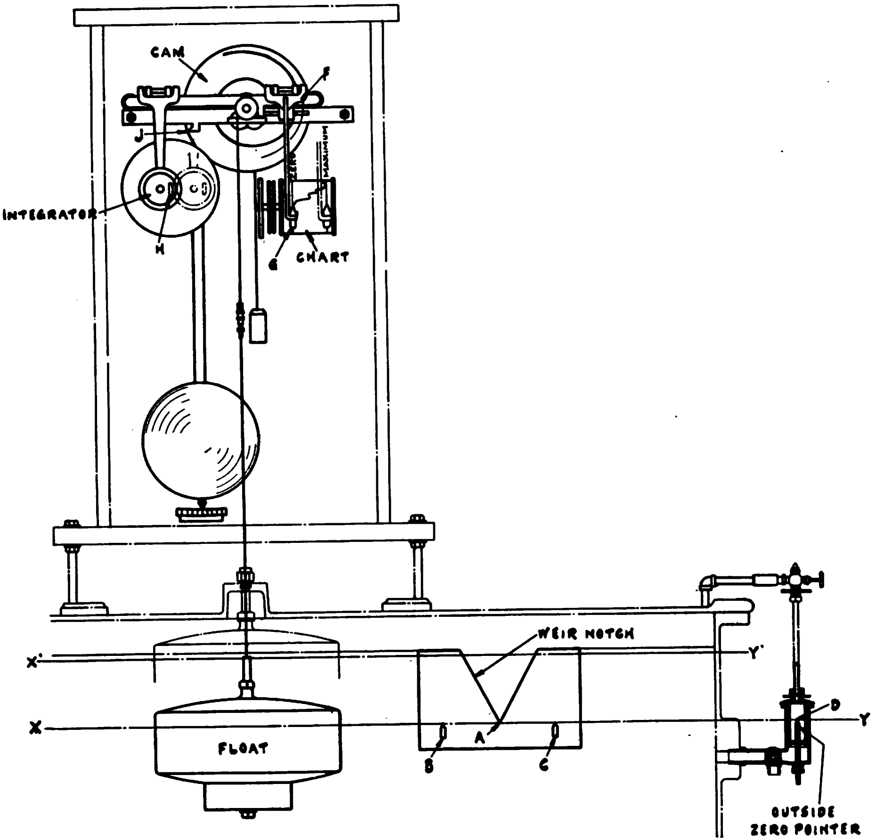
The main clock spindle driven by the weight drum carries a gear meshing with a pinion on an intermediate spindle. A bevel gear on this spindle meshes with a pinion on the spindle of the integrator disk, the motion thus being transmitted directly, without speeding up and speeding down again as is the case with commercial clock movements applied to work of this kind. The integrator disk is on the same level with the chart drum, so that the two are side by side, symmetrically placed in the case and at all times visible through the door. A gear on the spindle of the integrator disk drives the spindle of the escapement through a pinion, giving altogether only three gear reductions from driving weight to pendulum. The gears and pinions and spindle bearings are extra heavy and of large area.

The escapement is of the Graham dead beat type, making 80 beats per minute, instead of the 240 or 300 found in the hair spring escapements of commercial movements. The pendulum weighs 6 pounds. Pendulum clocks are readily adjusted and in a simple manner, and the use of one clock instead of two reduces the task of regulation to the minimum. A glance at the pendulum shows at all times whether the clock is running, and as the pendulum is pivoted to swing in both planes, it serves as a plumb-bob in lining up the case.

The clock and recorder parts are supported from brackets on a cast iron base, which is attached to the back plate of the case. The latter is built of heavy plate throughout, the bottom being flanged and of heavier material than the sides. The door is carried on three hinges, and is held closed by three-way draw-in bolts operated from a single lock. Felt gaskets around the door and on both sides of the plate glass window keep out dust. The edge of the door is flanged all the way around for stiffness.

The adjustment and care of the instrument is very simple. A locking device is provided for holding the cam disk in either the zero or the maximum positions, permitting of readily adjusting the pen and integrator roller to the corresponding positions on the chart and on the integrator disk respectively. After this adjustment has been made, the water (at the operating temperature) is drawn down to the zero level, as indicated by the auxiliary outside zero pointer, shown opposite. The cam disk is then released and the micrometer adjustment between float stem and cable manipulated until the disk stands at zero when controlled by the float. Adjustment in this manner at the working temperature eliminates errors due to expansion, contraction and change in submergence of the float in water at different temperatures. **The zero adjustment can be made while water is passing through the heater.**

Adjustment of Recorder

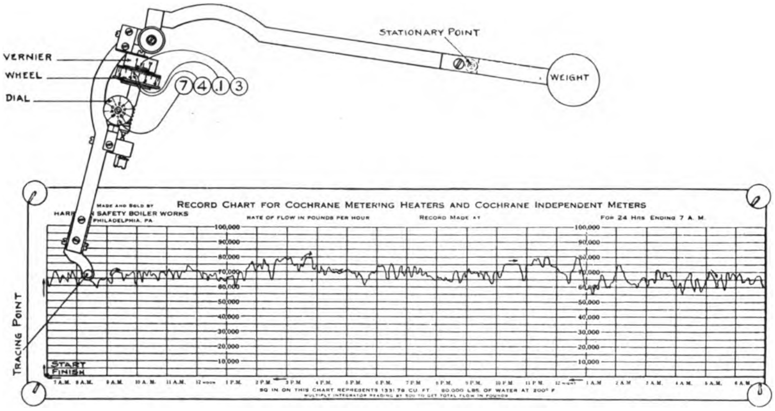


Zero and maximum adjustment

This diagram shows the simple method for setting the Cochrane Recorder in adjustment with the weir notch and the float.

The two points B and C soldered to the notch plate determine the zero level of the notch. With the float resting in water at this height, the cam plate is placed at the zero point J by adjusting the micrometer screw in the cable. Likewise the pen is set at the zero line on the chart by means of a micrometer adjustment for moving it to right or left, and the driving wheel of the integrator train is similarly placed at the center of the clock-driven disk.

In other words, it is only necessary to set the weir notch, float, cam plate, chart and integrator all at their zero points, which are readily determined, in order to adjust the Cochrane Recorder for service.



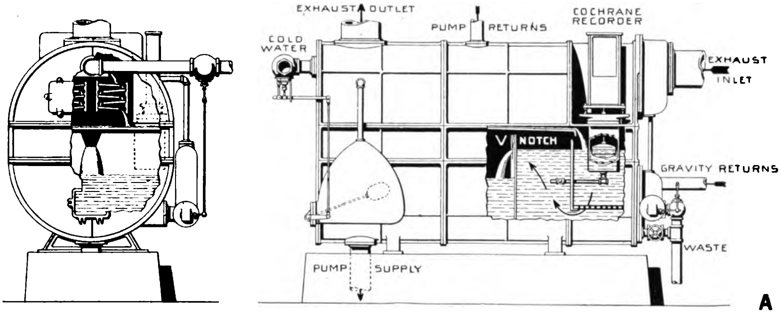
Method of using planimeter. The tracing point is moved completely around the area in a clockwise direction and the reading at beginning is subtracted from the reading at ending.

The chart from the Cochrane Recorder exhibits a continuous record of the rate of flow at each instant. As length on the chart represents time and height of chart rate of flow, the area under the record line obviously represents amount of water which has flowed in the elapsed period. This area is readily determined by means of a planimeter, and the amount of water, in pounds or cubic feet, is obtained by multiplying by an appropriate factor.

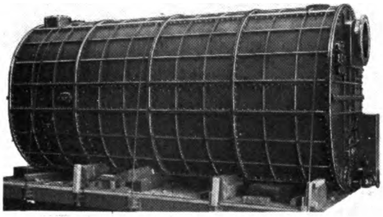
Special Metering Heaters

Cochrane Metering Heaters are designed for all situations in which open feed water heaters are ordinarily installed. The **horizontal elliptical type of metering heater** is used in locations where head room is limited, and is also to be recommended where there is heavy back pressure. The Cochrane Metering Heater shown in cut C opposite was designed to operate under 15 pounds back pressure, and was tested to a pressure of 20 pounds per square inch. Three notches, for capacities of 50,000, 100,000 and 200,000 pounds per hour, were supplied, to be used at different seasons of the year. That is, the full chart ordinate can be used for each of these capacities, giving a much greater accuracy at small flows than would be the case with only one notch of the maximum capacity. To prevent

Horizontal Elliptical Metering Heaters



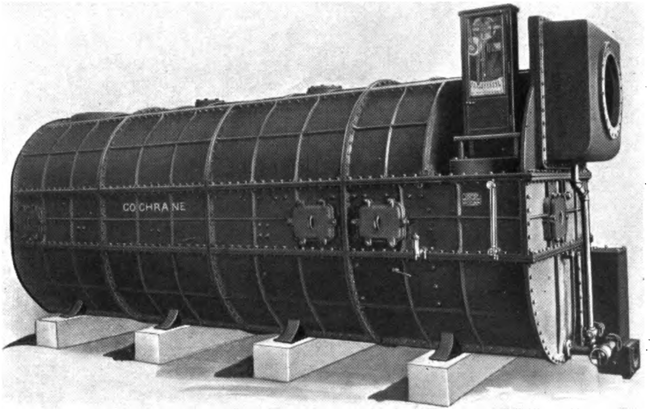
A



B

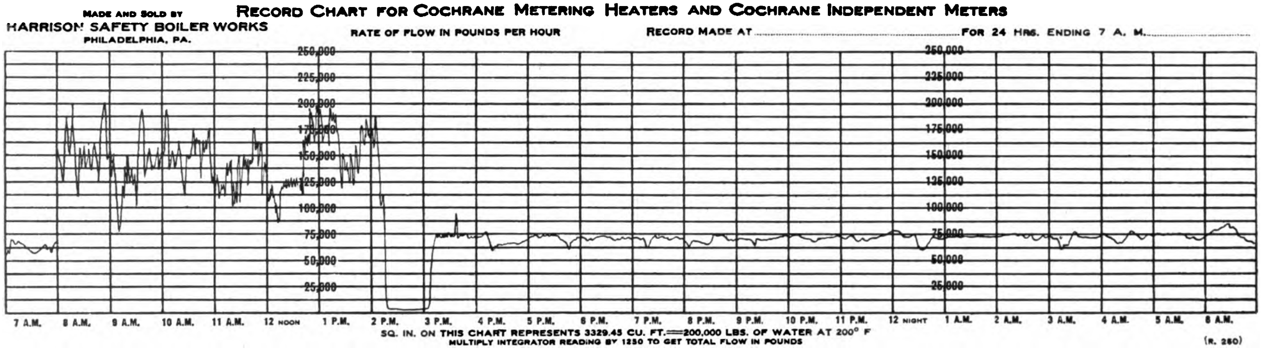
COCHRANE HEATERS-SEPARATORS-VALVES
-- HARRISON SAFETY BOILER WORKS, PHILA --

C

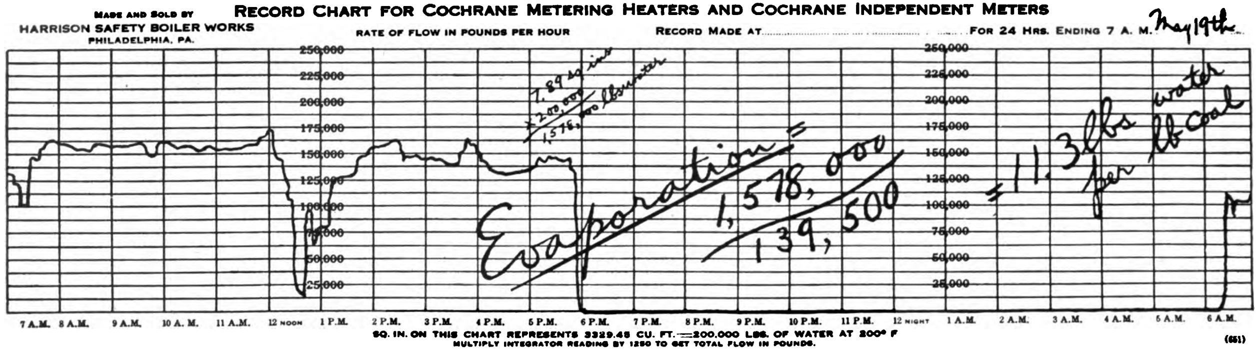


D

Cochrane Metering Heaters of the horizontal elliptical type, for low headroom



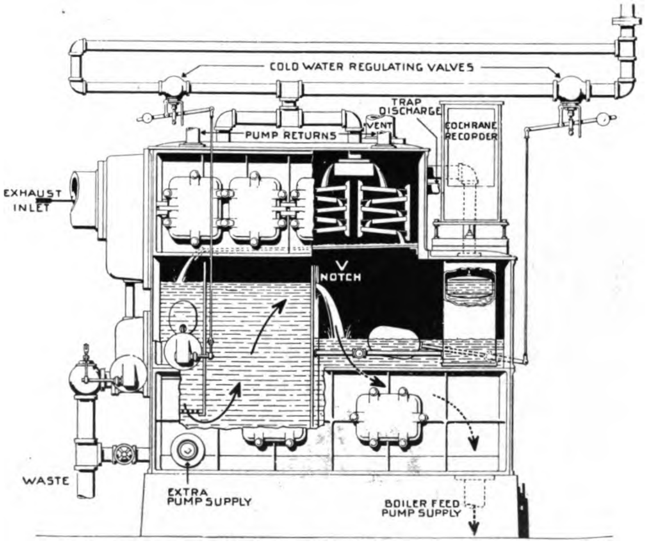
Cochrane Meter Chart from plant having heavy morning load



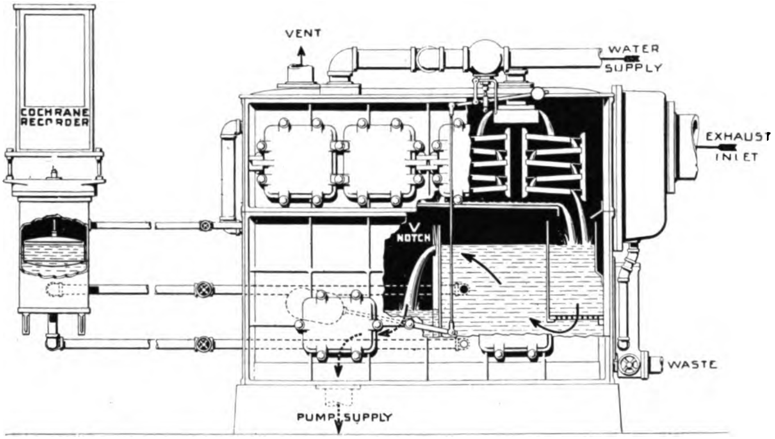
Cochrane Meter Chart from Manufacturing Plant operating in day-time only the accumulation of scale on the notch plate, a special **brush** is fitted, permitting the notch to be cleaned while the meter is in service.

Multiple notch meters are sometimes fitted with special gates so that individual notches can be closed off while the meter is in operation, making it possible to secure an open, easily read chart when running at fractional flows.

Where water is taken from the one heater for several different purposes, as for boiler feeding and for industrial purposes, in paper mills, dyeing establishments, etc., it may be desired to meter only one of the supplies, as the boiler feed water. This is illustrated by the metering heater shown below, which was supplied to a large pulp mill. The water for the boilers passes over the weir, while water for beater engines, etc., is taken from an extra pump supply opening shown on the side of the heater at the lower left hand corner of the drawing.

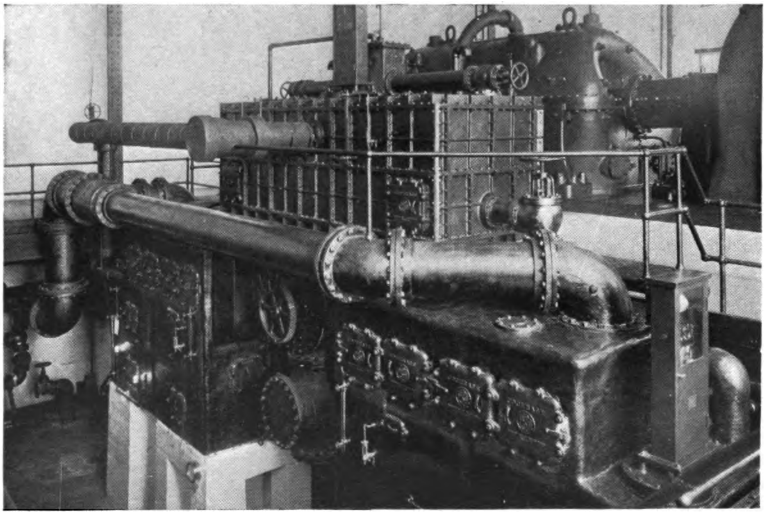


Cochrane Metering Feed Water Heater in which hot water used for boiler feeding is measured, hot water used for other purposes not passing over the weir



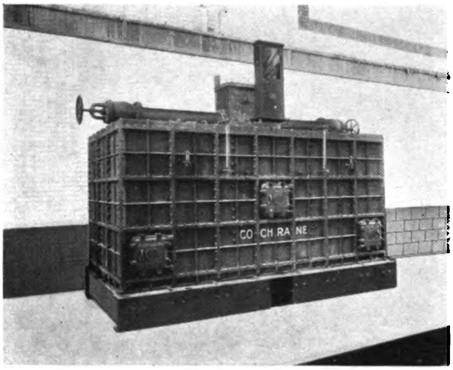
Cochrane Metering Heater with recorder float chamber placed at a distance

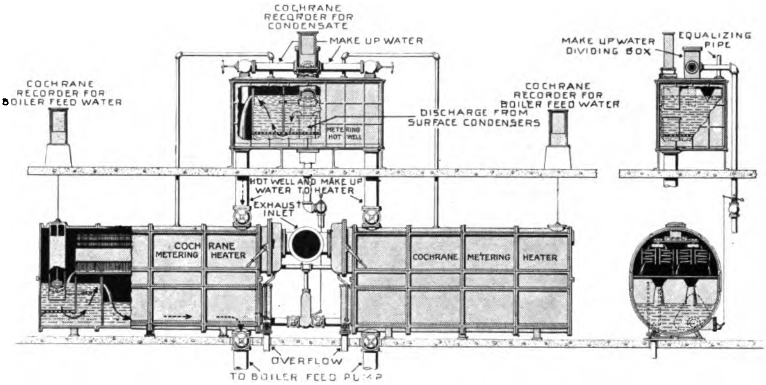
The Cochrane patented double unit arrangement of heaters, especially adapted to plants of large capacity, as 50,000 kilowatts or over, is carried out with Metering Heaters. The dividing box from which the water supply is distributed to the two heaters may take the form of a metering hot well, wherein the returns from condensers are measured separately from the raw make-up water.

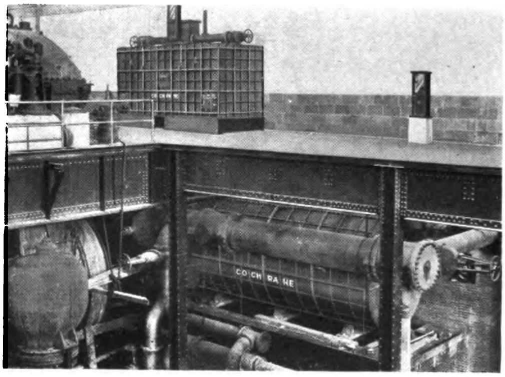


Two 6,000 horse power Cochrane Metering Heaters and one 500,000 pounds per hour Metering Dividing Box installed in an electric central station on the double unit principle

Double Units




COCHRANE RECORDER FOR CONDENSATE
MAKE UP WATER
MAKE UP WATER DIVIDING BOX
EQUALIZING PIPE
COCHRANE RECORDER FOR BOILER FEED WATER
COCHRANE RECORDER FOR BOILER FEED WATER
DISCHARGE FROM SURFACE CONDENSERS
METERING HOT WELL
HOT WELL AND MAKE UP WATER TO HEATER
EXHAUST INLET
COCHRANE METERING HEATER
COCHRANE METERING HEATER
OVERFLOW
TO BOILER FEED PUMP



Cochrane Patented Double Unit Metering Arrangement installed in power station

The Cochrane Metering Hot Well on the upper floor measures the condenser returns, automatically admits the required amount of make-up water and divides the whole into equal parts, which pass to the two Cochrane Horizontal Elliptical Metering Heaters below. All three recorders are located on the turbine room floor. Capacity, 1,200,000 lbs. per hour. See also page 65.

The Cochrane O-Series Metering Heater

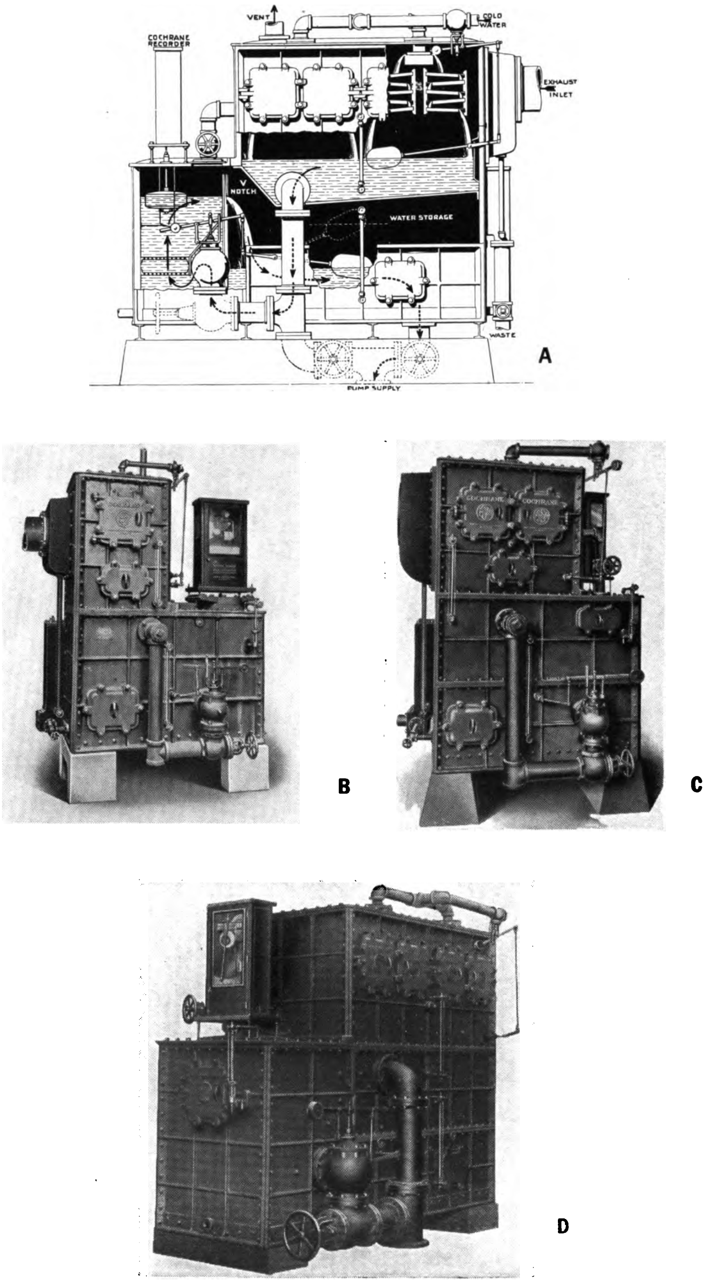
The Cochrane O-Series Metering Heater consists essentially of an independent heating chamber and an independent meter chamber, the heater chamber being superposed upon the meter chamber so that together they form one structure. The admission of cold water to the heater part is controlled by a float in the heater storage space, and in case of an excess accumulation of water in the heater, as through leakage of the cold water valve, or heavy flushes of returns from heating systems, etc., the surplus will overflow over the skimming weir of the heater and through the trap or water seal. That is, the heater performs its normal functions without reference to the meter.

The meter receives water through a pipe connection from the heater chamber, a float in the outflow chamber of the meter controlling a balanced valve in this pipe. The admission of water to the meter is therefore controlled entirely by the level of water in the outflow chamber, that is, by the rate at which pumps withdraw water from the latter.

There is in addition a vapor pressure equalizing pipe connecting the steam space of the heater with the steam space of the meter, according to our patents, permitting of metering water at temperatures above atmospheric boiling point, as where back pressure is carried upon the heater, and avoiding the troubles which arise where a heater discharges into an independent meter vented to atmosphere or completely enclosed, as discussed on pages 26 and 27.

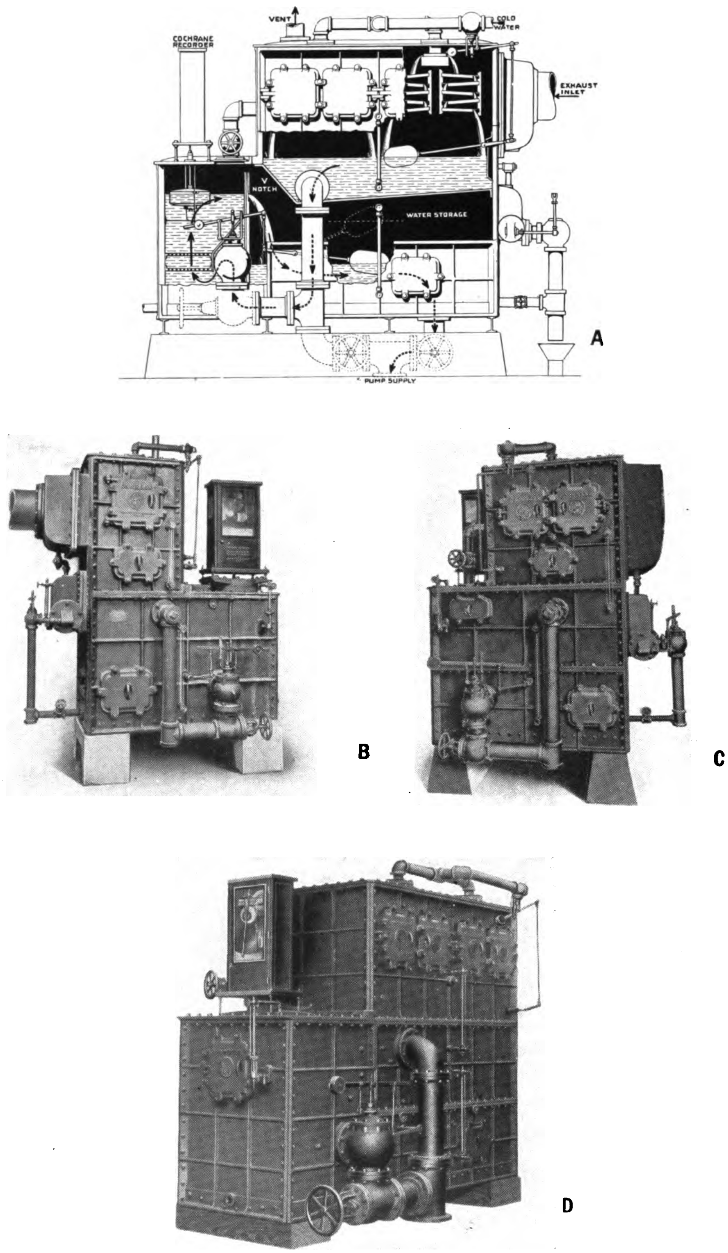
The Cochrane O-Series Metering Heater involves the use of more material, the making of more joints, and an additional, large-size regulating valve and float, and is therefore more costly to build than the Cochrane Standard Metering Heater. On the other hand, by supplying suitable piping connections the meter portion can be used independently of the heater, or the heater independently of the meter. For example, the boiler feed water can be passed directly from the heater to the

O-Series Metering Heaters



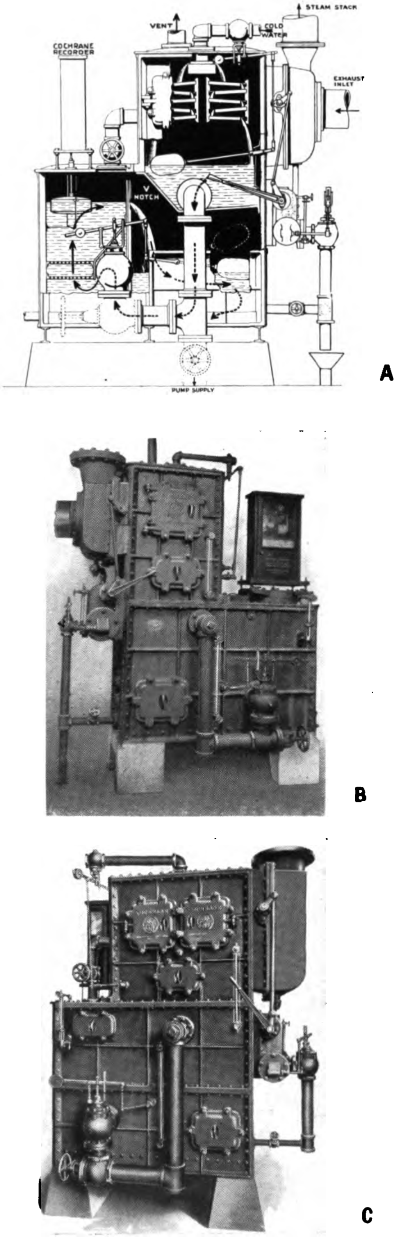
Cochrane Metering Heaters with isolated meter chambers, free exhaust type
(O-24,000 Series)

O-Series Metering Heaters, Back-Pressure Service



Cochrane Metering Heaters and Receivers with isolated meter chambers, back-pressure service
(O-25,000 Series)

O-Series Metering Heaters



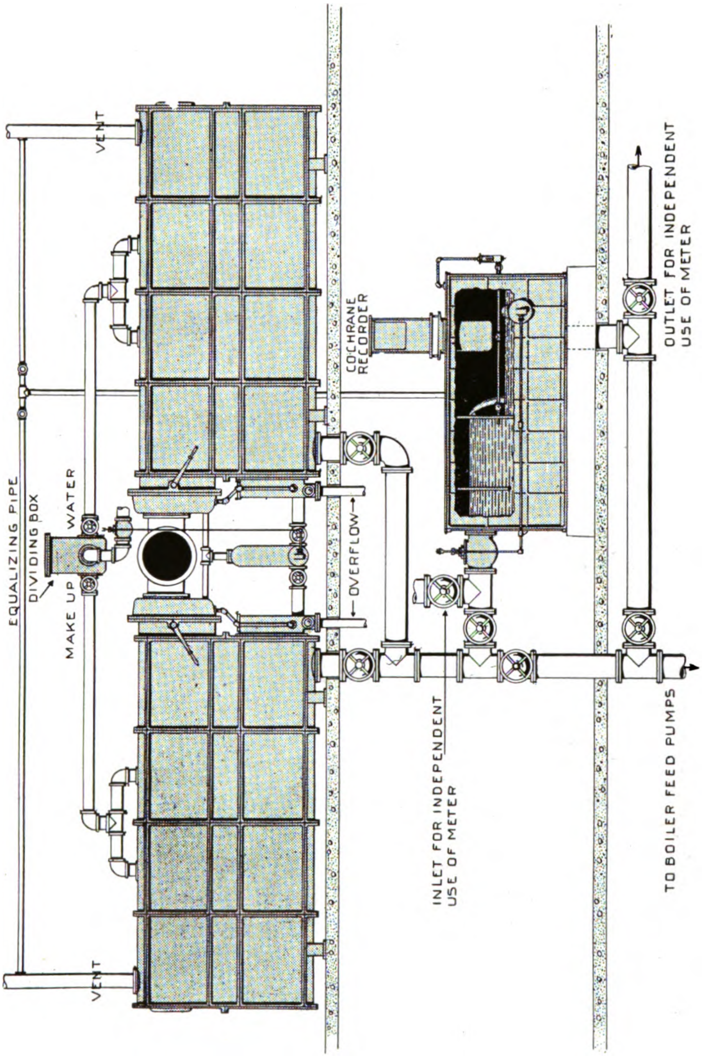
Cochrane Metering Steam-Stack and Cut-Out Valve Heaters and Receivers with isolated meter chambers
(O-27,000 Series)

boiler feed pumps, while the meter is opened for inspection. It is not claimed, however, that it is possible for a man to enter the meter for cleaning or repairs at such times, as the temperature is too high.

It is also possible to meter the boiler feed water while the heater is opened for cleaning or other purposes, thus keeping a complete and continuous record of the boiler feed supply, or by installing suitable piping connections the meter can be used for measuring condensate while the heater is in use supplying the boilers with hot feed water.

The O-Series Metering Heater is recommended especially where the heater receives uncontrolled returns, as from live steam traps or heating systems or condenser hot well pumps, as under such circumstances the level of the water in the still water chamber will not be affected by the irregular discharge of water into the heater, and the charts produced by the meter will be fairly smooth and uniform, and free from the rapid variations in rate of flow that would be caused by such sudden and irregular discharges of water into a standard metering heater.

At the same time, because of the greater simplicity of the standard metering heater and less headroom required, it will be preferable in many cases where irregular returns of condensate or trap discharges are to be expected to install a returns tank, from which the metering heater can draw its supply in the ordinary manner, or a standard metering heater can be equipped with a second float and regulating valve which will pass to waste or to a storage tank surplus water entering the distributing or returns trough. The type of metering heater to be preferred will depend upon local conditions, and our Engineering Department will gladly assist with suggestions, upon receipt of information and sketches showing the proposed layout.



Two Cochrane Open Feed-water Heaters in our Multiple Unit Arrangement delivering Water to a Cochrane Independent Meter Installed According to our Patents

Cochrane Independent Meters

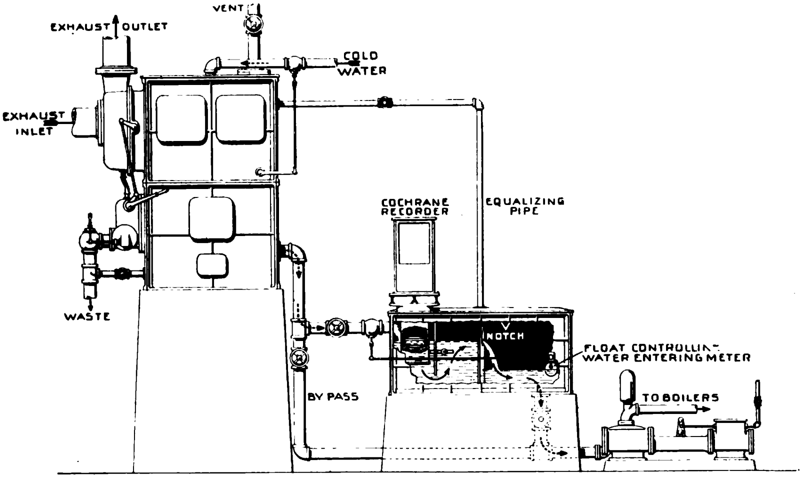
The Cochrane Independent Meter consists of a weir mounted in a suitable chamber in connection with a Cochrane Recorder, as shown on pages 64 and 67. If used in connection with an open feed water heater, the latter can be operated in the ordinary manner, a control valve actuated by a float in the outflow compartment of the meter being inserted in the pipe connecting the heater and the meter. To obviate differences in pressure between the vapor space in the heater and the vapor space of the meter, the two are connected by an equalizing pipe, a patented feature which is absolutely essential to the satisfactory operation of independent meters used in connection with open heaters, wherever back pressure is carried and the water is heated above 212° F.

In connection with a closed heater, the Cochrane Meter serves as a hot well or receiver for condensed returns and for the drips from the closed heater itself, which can be conserved if the heater is protected by an oil separator. The float in the outflow chamber controls the introduction of make-up water, thus serving as a make-up water regulator. Where returns come back in excess of the demands of the boiler feed pump, a second float may be fitted in the outflow chamber to control a valve in the return line, so that excess returns over what can be stored in the outflow chamber will be diverted to a storage tank or to waste. The Cochrane Independent Meter can be used with closed heaters of any standard type.

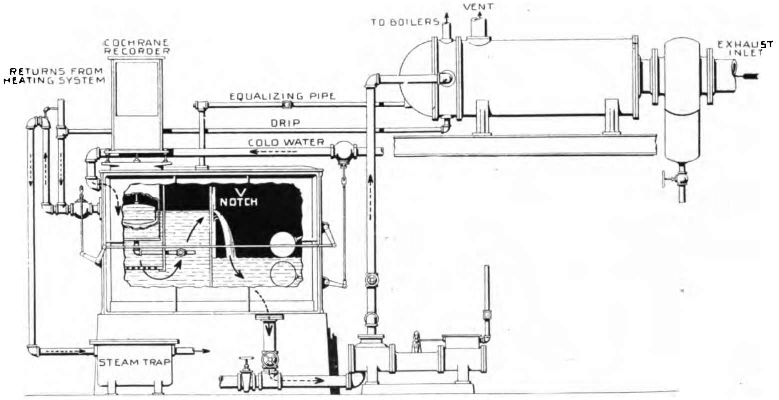
The Cochrane V-Notch Meter as an Efficiency Indicator for Engine or Turbine

The measurement of condensate from a turbine or engine is even more important than the taking of indicator cards, since it gives a continuous, reliable indication of efficiency. The information supplied by the Cochrane Meter is positive and final, whereas that supplied by an indicator card is only inferential, and the inference may or may not be correct. To one skilled in the use of indicators, the diagram may show when valves are leaking or improperly set, or when piston rings are not tight. But many operating men have not

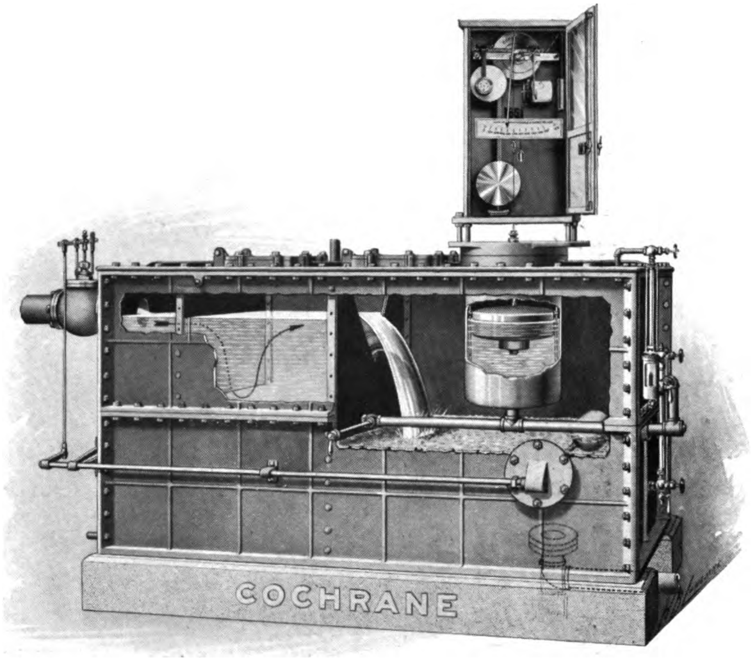
Independent Meters



Patented method of installing meter in connection with Open Feed Water Heater, by which annoyance from escape of vapor and loss of heat when water is above 212 degrees F., as with back pressure, is prevented.



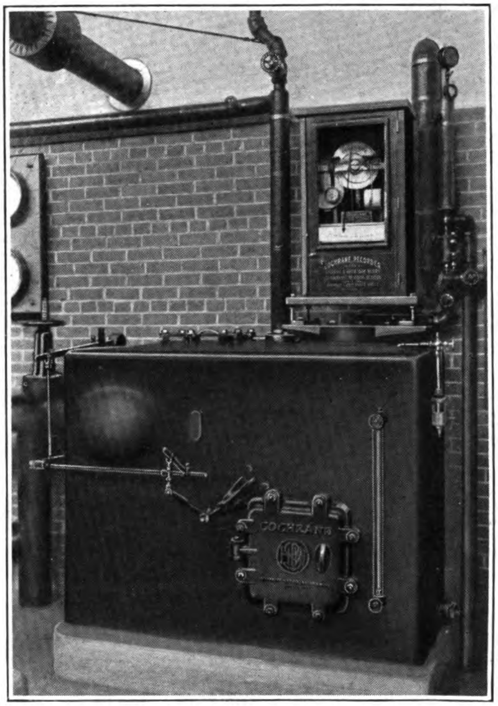
Cochrane Feed Water Meter arranged for use with closed heater in connection with exhaust steam heating system. Meter serves also as hot well for returns and acts as automatic make-up water regulator.



Cochrane Independent Meter with special float chamber and outside zero pointer

arrived at this degree of skill, and in any case the information supplied by the indicator card is inconclusive; that is, the facts as to steam consumption, the real thing at issue, are not known. The Cochrane Meter registers net results. When these net results are inferior to those given by the engine when new and properly tuned up, it is time to look for something wrong.

The Cochrane Meter is the proper indicator for the steam turbine. It will show when the blading has become eroded by wet steam, or filled up with sludge brought over from priming or foaming boilers. It will tell when the blading has been damaged by rubbing, and when the steam packings between stages are imperfect. With turbines the nozzles of which are



Cochrane Independent Meter Installed in Municipal Plant

turned on or off by hand to maintain high efficiency it will record whether or not the attendant has been faithful to his duties.

The Cochrane Patented Combined Metering Hot Well and Dividing Box for use in connection with Cochrane Meters or Metering Heaters installed according to the double unit arrangement has already been mentioned. In this apparatus, shown on page 55, the condensate from the hot well pump discharges through two notches in equal quantities to the two heaters, the amount being measured by the recorder. The cold make-up water is likewise equally divided, but is not metered. The total feed is thus measured by the recorders of the two metering heaters, and the condensed returns by the recorder of the metering hot well, while the make-up water is the difference obtained by subtracting one amount from the other. The admission of make-up water is controlled by a float in a chamber communicating with the outflow chambers of the two metering heaters. With this arrangement, either metering heater can be cut out of circuit for inspection or cleaning without interfering with the operation of the other metering heater or of the metering hot well.

Cochrane Meters in Connection With Steam Heating and Drying Systems, Processes, etc.

Where steam is supplied to heating systems, or to drying, cooking or other apparatus in which it is condensed, it is sometimes desirable to know how much steam is used in each building or by each process. This can readily be determined by installing a Cochrane Meter for measuring the condensed returns. Such meters can be of the multiple type with individual weir chambers and recorders for each turbine in the plant. The Cochrane Meter is in many cases indispensable to cost accounting.

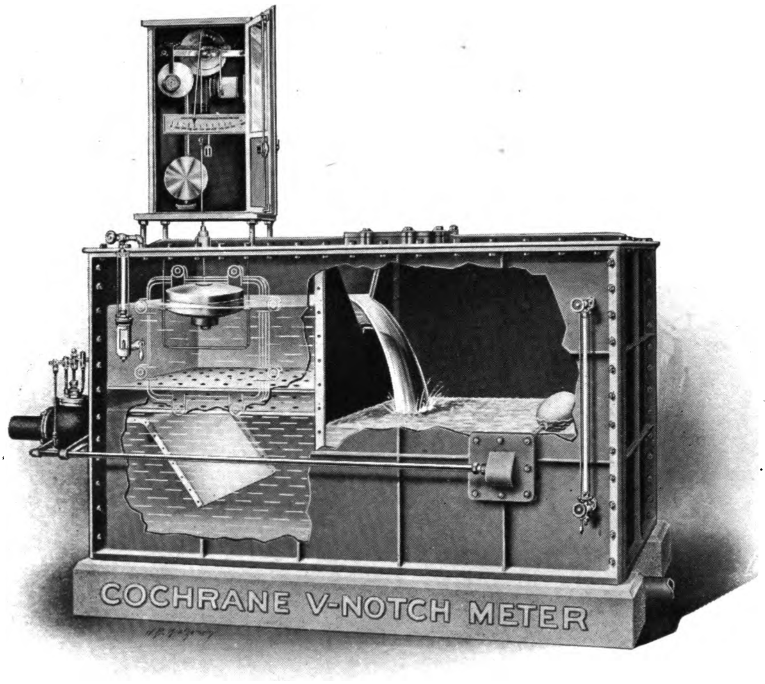
Cochrane V-Notch Meters are also adapted for **measuring acids, bleaching liquors, dyes, cyanide solution, chlorinating or electrolytic solutions, salt solutions, sewage, solutions for treating water in water works, liquids in paper mills,** etc., etc. Copper, lead, brass or enamel-lined tanks with notches of special material are supplied where required.

Steel Plate Meter Chambers

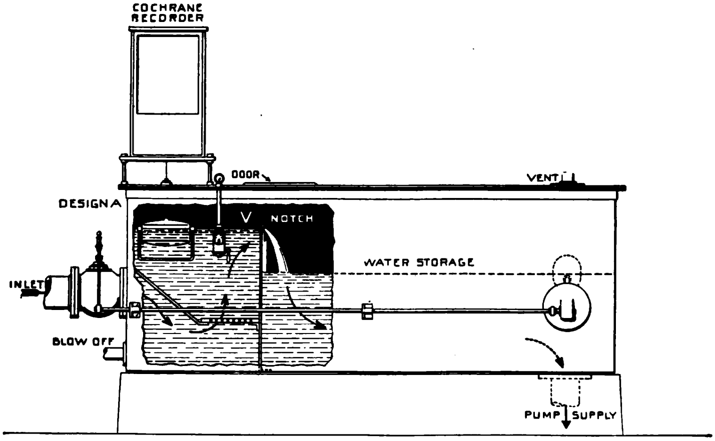
The standard cast iron construction for Cochrane Independent Meters is shown on pages 64 and 67. The walls and baffles are of heavily ribbed cast iron plates, similar to those used in Cochrane Heaters, while the valves, floats and other fittings are of the same high grade.

Cast iron construction is recommended for Cochrane Meters as well as Heaters because of its greater durability. Under certain circumstances, however, the lightness and cheapness of steel plate construction are desirable, and to

Independent Meters

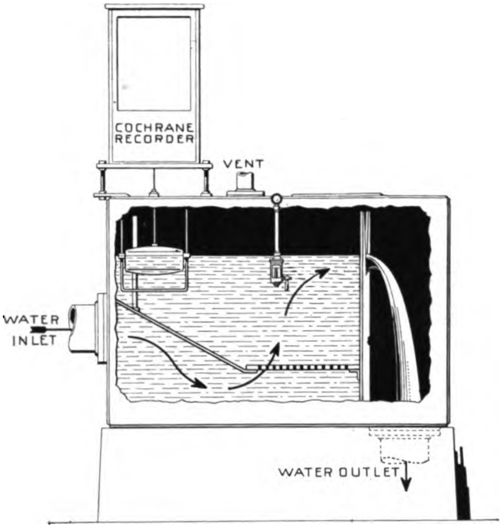


Cochrane O-Series Independent Meter with float resting directly on water in approach chamber

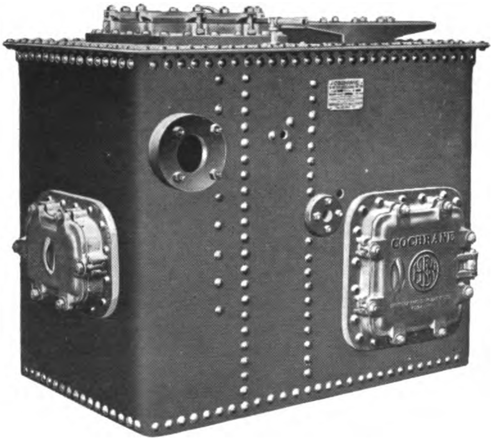


Cochrane Independent Meter with extra storage capacity

Cochrane Meters



Cochrane Independent Steel Plate Meter for measuring condensate and other liquids where control valve is not required



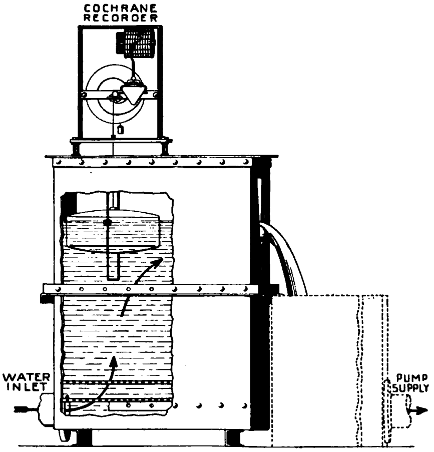
Cochrane Steel Plate Meter Tank (Recorder not shown).

meet such requirements we supply the type of meter shown opposite, which illustrates a design suitable for metering the discharge of condenser hot well pumps, in connection with which a regulating float and valve are not needed.

Cochrane Independent Meters when used for **measuring condensate from surface condensers** are not fitted with control valves, as the water must be allowed to flow freely from the hot well pump. By running a header the length of the turbine room, with a branch to each condenser, it is possible to use the meter for testing the efficiency of any unit. Where continuous records from all units are desired the **Multiple Recorder** type of meter is used.

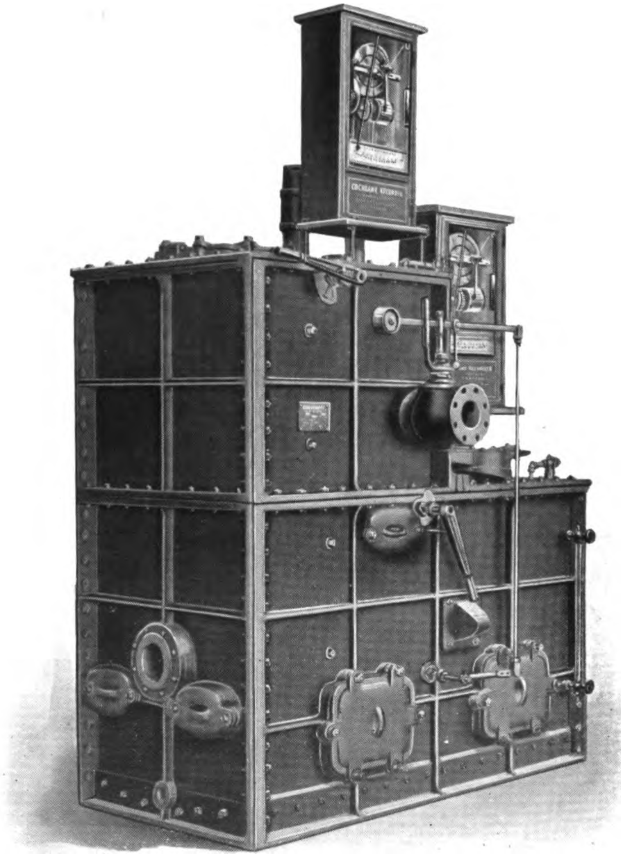
Portable Meters

Consulting engineers in private practice and connected with large corporations find the Cochrane Portable Meter, as shown below, useful for making tests on individual boilers or batteries of boilers, steam turbines, steam engines and similar uses. The meter, which is built of steel plate well reinforced by angles and channels, and with special facilities for handling, consists of inlet and still water chambers only, the water from the notch being received in a tank, funnel or other receptacle, according to circumstances. The over-all height of the meter is 45 inches, and the area occupied 30 inches square. The maximum capacity may be anything from 5,000 to 125,000 pounds per hour. The instrument is fitted with appropriate spare cable drums, so that the entire chart height will be utilized for the smaller capacities. Provision is made for storing the recorder within the meter tank during shipment.



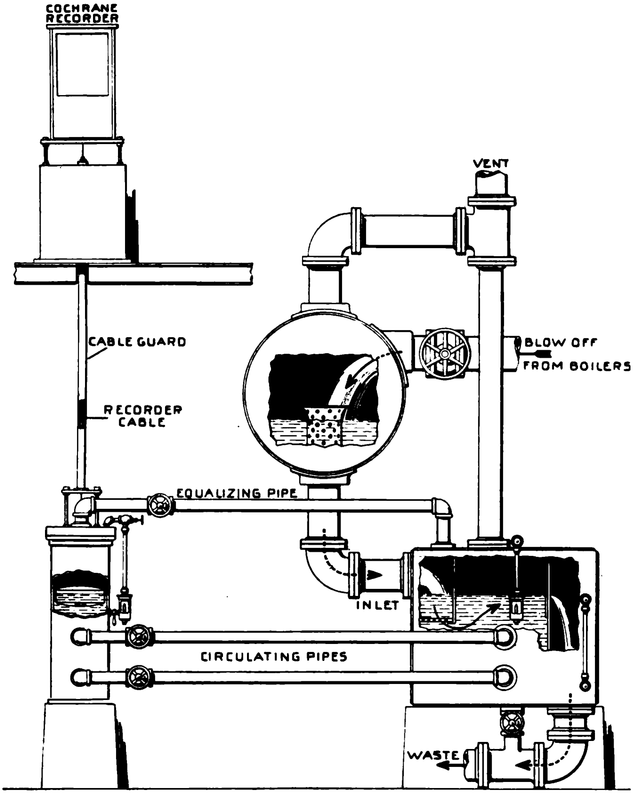
Portable Meter, with Demountable Recorder

Measurement of boiler blow-off is desirable for the highest efficiency. The presence of the meter in the blow-off connection will likewise serve to detect leakage of blow-off valves, a frequent source of large, unsuspected loss. An arrangement for using Cochrane Meters for metering blow-off is shown opposite. By the use of two pens in the recorder, leakage is recorded on a greatly magnified scale.

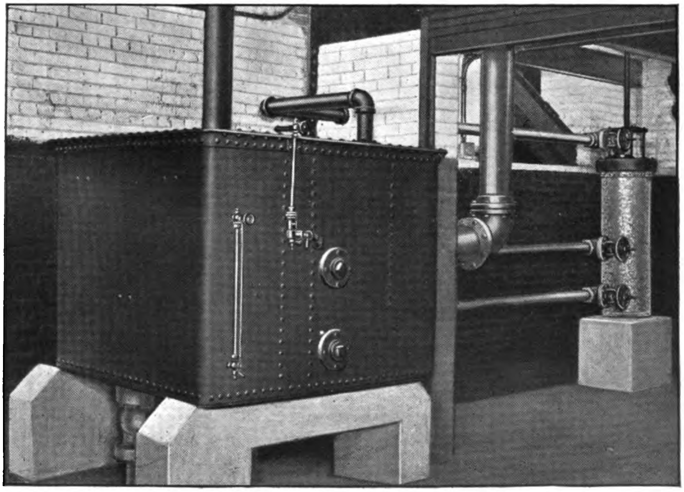


Cochrane Duplex Meter, with separate notches and Recorders for measuring make-up water and total boiler feed independently

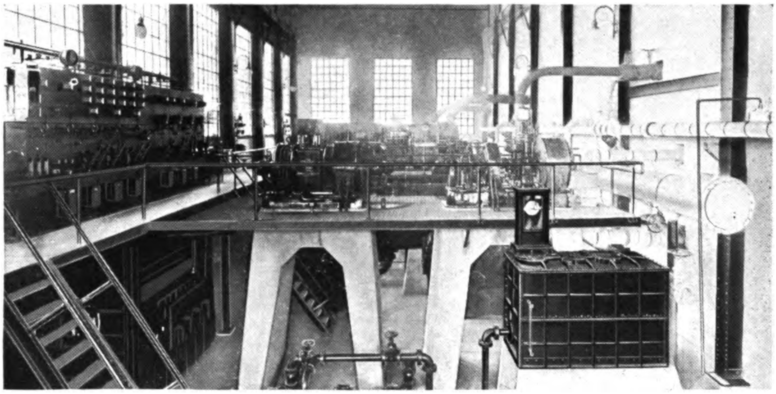
Blow-Off Meter



Cochrane Boiler Blow-Off Metering Arrangement



Cochrane Blow-Off Meter. The Recorder is located on the floor above



Cochrane Independent Meter in central station plant

ACCURACY OF THE V-NOTCH

The suitability of the V-Notch for measuring small and medium quantities of water early suggested itself to hydraulic engineers, probably because the geometrical figure of the cross section of the stream is always the same regardless of the head, thus eliminating the varying effects of end contraction experienced with weirs of rectangular and other outlines.

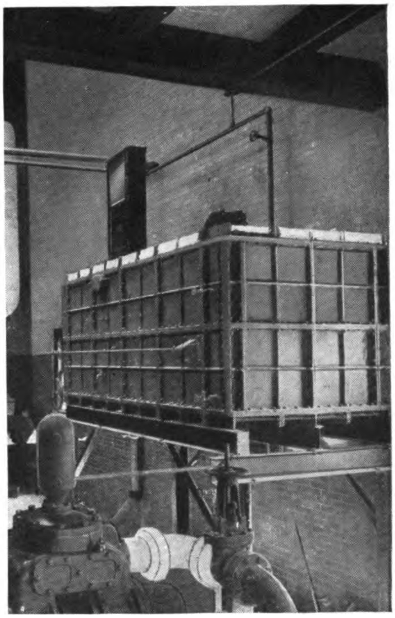
The first careful investigations of the properties of the V-notch were made by James Thomson, Professor of Civil Engineering at Queen's College, Belfast, and at Glasgow University, and were first published in 1858 and 1863. Professor Thomson deduced for the 90 degree notch the formula $Q = .305 H^{5/2}$, wherein Q is the flow in cubic feet per minute and H the head in inches of the still water surface above the apex.

Subsequently, in 1907 to 1909, more elaborate and refined experiments were made by Mr. James Barr, Carnegie Research Scholar at the James Watt Engineering Laboratories of Glasgow University, under the supervision of Mr. Archibald Barr, Professor of Engineering at that school. Mr. Barr's report is reprinted in *Cochrane Engineering Leaflet No. 18,* which will be sent upon application. His conclusions are that the head on the notch can be read within 1/500 inch, and that the flow deduced therefrom is correct to within one-third of 1 per cent.

Cochrane Testing Laboratory

When it was decided to use the V-notch form of weir in the Cochrane Metering Heater, accurate knowledge was desired, not only of the performance of the 90 degree notch installed under ideal conditions of approach channel, as in Barr's experiments, etc., but also to investigate the action of notches of various angles in meter chambers of such dimensions as would be supplied commercially.

Multifold investigations of this character by means of the appliances used by Barr would have involved almost unlimited time and expense. The design and construction of a special testing plant was therefore undertaken, the method of testing being based upon the use of a master meter calibrated by methods similar to those used by Barr. With this standard meter, the constants of the weirs and weir chambers used in Cochrane Meters are accurately determined. The Cochrane Meter Testing Laboratory has been described in a paper by W. S. Giele before the American Society of Mechanical Engineers, reprinted in *Cochrane Engineering Leaflet No. 18.*



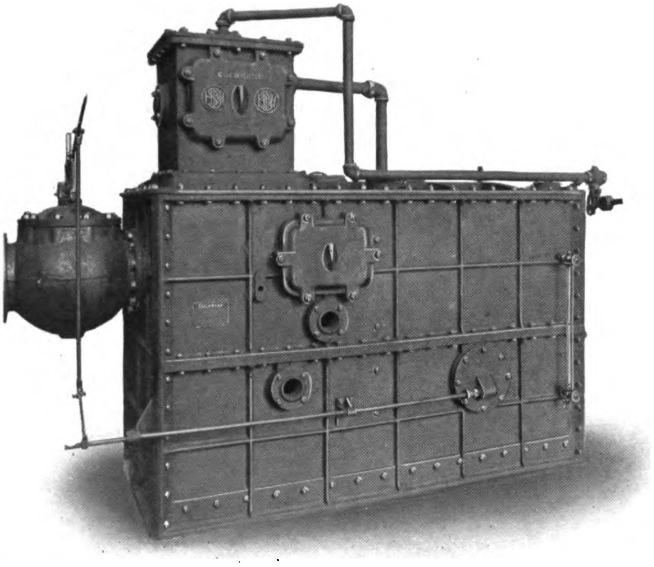
Cochrane Independent Meter

Temperature Correction and Guarantee

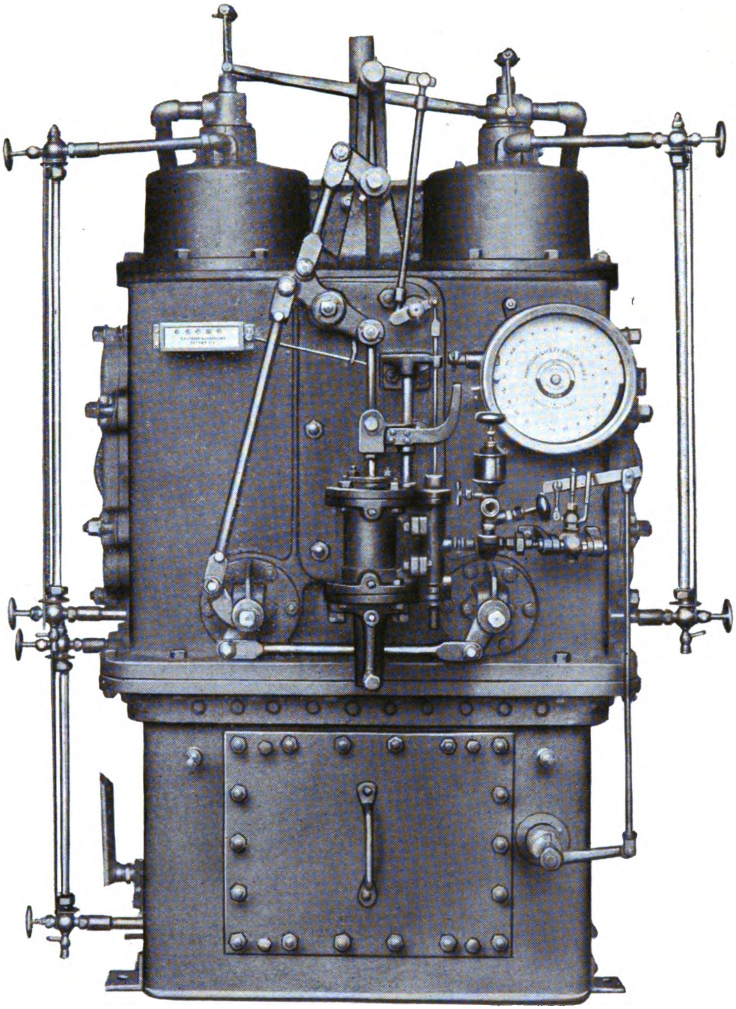
The formula for the V-notch weir states the flow in cubic feet, and the volumetric rate of flow at a given head is always the same irrespective of the temperature of the water. The density of water varies, however, from 62.4 pounds per cubic foot at 39 degrees F., the temperature of greatest density, to 59.8 pounds per cubic foot at 212 degrees, or atmospheric boiling point, so that in order to have the recorder to give results in pounds, as usually desired when metering boiler feed water, the temperature must be known beforehand. We guarantee the accuracy of Cochrane V-Notch Meters to be within 1½ per cent. of absolute weight, irrespective of temperature variations not exceeding 25 degrees above or below the temperature specified.

OTHER FORMS OF WEIRS

The Cochrane Recorder is also well adapted for use in connection with forms of weir other than the V-notch, as, for instance, the rectangular form, which is sometimes preferred because of its great capacity, or with orifices. Specially cut cams are supplied to record the flow over weirs of any shape or through an orifice; but a higher degree of accuracy can in general be obtained with our standard V-notches, the properties of which have been investigated in our testing plant. Wide bottom weirs are, however, useful for measuring the discharge of streams, flow of sewage or irrigating water and other purposes where V-notches would require an inconveniently high head.



Special V-notch meter combined with small live-steam heater for heating water which has been used for cooling bearings. Outside float chamber and distant recorder are used.



The Cochrane Precision Meter, for feed water, oil or condensate

THE COCHRANE PRECISION METER

Where the greatest accuracy is demanded, we recommend the Cochrane Precision Meter. This meter is of the volumetric type, and is especially convenient as a test meter, since accurate leveling up is not required. It is also useful where a stable foundation cannot be had, as on shipboard. Its great accuracy renders it particularly suitable for the measurement of condensate, liquids from vacuum pans, chemicals, volatile oils, creosoting liquors, etc., for which purposes it is, where necessary, made of special materials to prevent corrosion.

Cochrane Precision Meters have been installed permanently on a number of battleships and are also used on trial trips as a check on fuel oil consumption. The instantaneous record facilitates prompt adjustment and co-ordination of the several parts of the equipment and remedying of losses due to such causes as air binding of closed heaters, excess back pressure on auxiliaries, defective insulation of steam piping, and various other factors which reduce efficiency and increase oil consumption.

The principle upon which the meter operates is the same as that employed by chemists for the exact measurement of liquids, for which purpose they use flasks having slender necks upon which graduations are marked, the diameter of the neck of the flask being so small in comparison with the body that even a considerable difference in level amounts to only a very small fraction of the total volumetric contents.

The Cochrane Precision Meter consists essentially of two calibrated measuring tanks, each fitted at its highest point with a narrow part or chamber in which there is a float, the two floats being connected to a walking beam which operates a steam valve admitting steam to a piston operating the valves by which the two measuring tanks are alternately filled and emptied. Each float almost completely fills its chamber, so that the volume of water represented by 1 inch rise around the float is only one-thousandth of the volume of the metering compartment, thus making it easily possible to secure an accuracy of volumetric measurement within one-half of 1 per cent. If the temperature and density of the liquid are known, the total liquid handled can be computed with the same degree of accuracy.

To explain the operation of the device, we will suppose that the liquid is flowing into the right hand compartment, and out from the left hand compartment, as indicated by the position of the valves. As soon as the water level reaches the float in the right hand compartment, it will shift the steam valve to such a position that communication is opened to the lower end of the cylinder containing the piston which operates both inflow and outflow valves. The piston will not move, however, until the left hand compartment has finished emptying, allowing the float in the storage compartment to drop sufficiently to admit steam through the throttle valve shown in the steam connection to the valve chest. **In other words, one of the measuring compartments must be completely full and the other completely empty before the inlet and outlet valves can be reversed.** Where the liquid can flow away freely, the storage chamber and the throttle valve are not required.

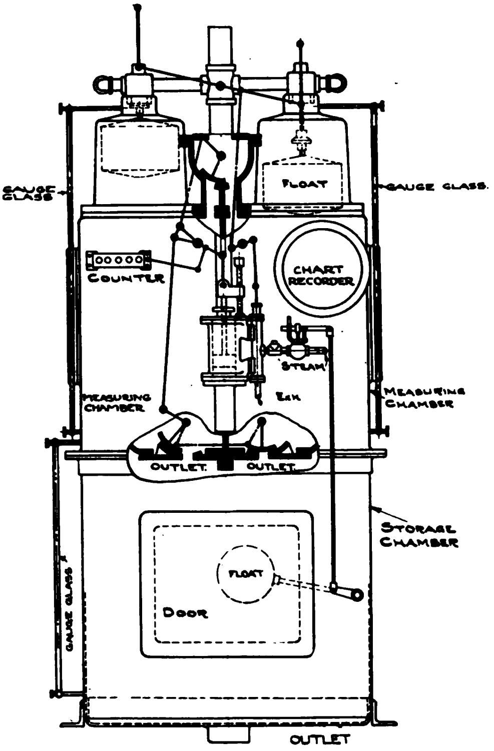


Diagram illustrating principle of Cochrane Precision Meter Note that valves cannot throw until one chamber is completely emptied and the other completely filled.

A counting train connected to the moving parts records the total flow over any given period, while the rate of flow is indicated by the frequency of register marks made on a clock-driven chart.

As the meter chambers can be vented back to the source of water supply, it is possible to handle water at any temperature, including where the water is heated in open feed water heaters under back pressure.

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Data Sheet, Cochrane Metering Heaters and Cochrane Independent Meters

Kindly furnish data asked for in order that we may submit recommendations. HARRISON SAFETY BOILER WORKS, PHILADELPHIA, PA.

1. Total horse power of boilers..........
2. Number and kind of boilers..........
3. Amount of exhaust steam available per minute..........lbs.
4. Fill out the table below for each engine, pump, etc.:

Type of Engine or Pump	Surface Condensing Units	Diameter Cylinder	Length of Stroke	Revolutions per Minute	Cut-Off	Steam Pressure	Hrs. Run per Day

5. Be sure to check all units run surface condensing (use column 2).
6. State approximate amount of surface condensing water that will be returned to heater (lbs. per minute)..........
7. Is exhaust steam used in heating or drying system?..........
8. State approximate amount of returns (lbs. per min.) from item 7..........
9. What back pressure, if any, is carried on exhaust?..........lbs. per sq. inch
10. Source of water supply (city, well, river, etc.)..........
11. Head or pressure of water supply..........ft. or..........lbs. per sq. inch
12. Average initial temperature of water supply..........degrees F.
13. What is average temperature of water delivered to boilers?..........degrees F.
14. How is water fed to boilers, by injectors or pumps?..........
15. How many gallons of hot water are required per hour for other purposes?..........
16. How often is water drawn and in what quantities?..........
17. Are you troubled with scale in boilers? Is it hard or soft?..........

    NOTE.—If you have an analysis of the water used for boiler feed, kindly forward a copy to us.

18. Do you use boiler compound?..........
19. A sketch showing the layout of the engine and boiler plant and pipe connections is usually of material aid in determining the best location for the heater, its pipe connections, etc.
20. How many hours per week is plant operated?..........
21. Amount to be measured per hour, in lbs. Maximum..........

    Average..........

    Minimum..........

22. If independent meter is to be installed in connection with open or closed heater, give sketch, showing layout, particularly vertical distance between pump supply opening on heater and suction opening on boiler feed pump.
23. Temperature of liquid to be measured..........maximum..........minimum..........
24. Where liquids other than water are to be measured, state nature, density and any peculiarities, such as viscosity, etc..........
25. If independent meters are to be installed to measure the discharge of condenser pumps, state whether discharge from meter is to pass directly to boiler feed pumps, to open hot well, or to open heater..........
26. Is it desired to measure separately the water from several different sources, as condenser pumps, the water to be delivered to a common destination, or is it desired to measure the water delivered from one source for several different purposes, as for boiler feeding, industrial purposes, etc.?..........

    Either arrangement can be provided in both the Cochrane Metering Heater and the Cochrane Independent Meter.

Name..........

Address..........

State..........Date..........191

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TO PLACE IN BINDER CUT OFF ON DOTTED LINE AND PUNCH TO REGISTER WITH HOLES IN FRONT COVER

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